MED-PC® for Windows
Programmer's Manual

Copyright © 1999, 2003 MED Associates Inc & Thomas A. Tatham

All rights reserved. No part of this manual may be reproduced in any form without prior, written permission of the publisher. Published by MED Associates Inc., P.O. Box 319, St. Albans, Vermont, 05478. (802) 527-2343 FAX (802) 527-5095

Trademarks: MED-PC, WMPC, MedState Notation; MED Associates, Inc.
Registered Trademarks: MED-PC; MED Associates, Inc
Turbo Pascal; Borland International, Inc.

TABLE OF CONTENTS

Chapter One: 1
Welcome To Programming In MedState Notation 1
Chapter Two: 2
Introduction to the Basic Concepts of Programming 2
Chapter Three: 9
An Introduction to #R, SX, ADD, and SHOW Commands 9
Chapter Four: 13
Controlling the Beginning and End of a Program 13
Chapter Five: 18
Creating a Program for an FR Schedule 18
(An Introduction to Z-pulses and Adding a Counter to Inputs) 18
Chapter Six: 23
Establishing Default Values for Variables and Using a Variable Time Input 23
(An Introduction to the SET and #T Commands) 23
Chapter Seven: 28
Decisions, Decisions, Decisions 28
(Introducing the "IF" Statement) 28
Chapter Eight: 37
Introduction to Arrays, Part One 37
Chapter Nine: 43
Array Commands As Outputs 43
(An introduction to the LIST, RANDI, AND RANDD commands) 43
Chapter Ten: 47
You Have Collected The Data, Now What? 47
(An introduction to Print and Disk Commands) 47
Chapter Eleven: 53
So How Does This Work 53
(The MED-PC: Theory Of Operation) 53
Appendix A: 62
MedState Notation Commands 62
INDEX 121

Chapter One:
Welcome To Programming In MedState Notation

Introduction

This newly revised manual has been designed to aid all users of the state notation language, MEDSTATE NOTATION (MSN), used with MED-PC® for Windows (WMPC™).

For the novel user, you will find that each of the following chapters introduces a couple of commands in MedState Notation and then allows you to write a program using those new commands. Each chapter builds on one another, so it is recommended that you read the manual from cover to cover, taking the time to try each tutorial. There should be no concerns about having to set aside large blocks of time to read the manual; the manual has been written in such a way that no one chapter should take very long to read. To get the most from each chapter you should type the program in the tutorial to test your new knowledge. Also, make sure to save the files with the names suggested (or at least keep track of the substituted names). The reason is you will see that many of the tutorials build on one another. Not only will this make it easier for you to switch from one tutorial to the next, it will also get you in the habit of going back to old code for ideas and/or shortcuts in programming.

For the intermediate user, you may find the chapters of some use, but if already familiar with most of the commands, you may just want to flip to the tutorials at the end of each chapter to brush up on MedState Notation.

For the experienced user, who is switching from MED-PC for DOS to WMPC, you may want to look at the first tutorial to see the differences in translating and compiling in WMPC and any refreshers you may need for codes can be answered in Appendix A.

Software Backup

In this age of hard drives and CD ROMS, many people overlook the need to back up their software. We at MED-Associates, however, advise everyone to make a backup of the distribution diskettes that have been supplied. Put the originals in a safe place and use the copies for installation. The procedure for making disk copies is found in the Windows 95/98 manual.

Before Getting Started

In order to get the most out of the tutorials at the end of each chapter, we recommend that you install WMPC on your hard drive and configure your hardware before starting to read this manual. If you have not already done so, consult the WMPC manual for step-by-step directions.

Chapter Two:
Introduction to the Basic Concepts of Programming

State Sets:

MEDSTATE NOTATION procedures are organized into blocks of code called state sets. There may be as many as 32 state sets within a single procedure, with each state set functioning autonomously with apparent simultaneity, as though each is an independent program. Within MedState, it is represented by the "S.S. #" where # is a number between one (1) and thirty-two (32) [1]. There may be no decimal point in the number and constants and variables in place of the number are not permissible. The periods following each "S" and the comma following the number are required.

States:

The basic unit of a state set is the State. At any given moment, a procedure can be thought of as being in a given state. When a procedure begins to execute, it is always in the first (i.e. top most) State. States are indicated by "S#", where # = an integer between one (1) and thirty-two (32) with the same restrictions on numbering as indicated for state set numbering.

Statements - General Description:

Statements are within States and are made up of commands. Comparing the basic elements of a program (e.g., state set, state, and statements) to the components of a book, the state sets are the chapters, the states are the paragraphs within those chapters, the statements are the sentences, and the commands are the words.

The Components of a Statement:

A statement is composed of three components: an **Input Section**, an **Output Section**, and a **Transition**. The input section consists of the commands to the left of the colon ":", the output section is between the colon and the arrow "--->", and the transition is to the right of the arrow.

A statement may be thought of as an IF - THEN - GOTO statement. For example, the following statement means, IF "Input" occurs THEN "Output" and GOTO "Next:"

```
Input: Output ---> Next
```

Actual code may look like this:

```
#R1: ADD A; ON 5 ---> S3
```

---

[1] State sets do not need to be numbered consecutively, nor do they need to be in ascending order, since state sets are processed in the order in which they appear in a procedure but each state set MUST have a unique number.

Typing Conventions

Case Is Irrelevant:

Upper and Lower case letters may be freely intermixed and used in any manner that best clarifies source code for a procedure.

Spacing And Blank Lines:

Spacing and blank lines are ignored. Again, this feature may be used to make source code statements as clear and as easy to read as possible.

Rules For Comments:

Comments are notes placed into the code that do not get translated into PASCAL. Comments may be placed on their own lines or following the end of any line containing MEDSTATE NOTATION code. Comments always begin with a backslash '\'. Please note that this is the same character as the DOS path separator, not the arithmetic division symbol, (/). Comments may not occur in the middle of a statement.

Legal examples:

```
\This is a comment before State Set 1 (S.S.1)
S.S.1,
\This is a comment before state 1
S1,
  Input: Output ---> Next
```

Illegal examples:

```
Input \This is the house light : Output ---> Next
```

Integers:

Integers are whole or counting numbers, such as 0, 5, 112 and 3000, which do not contain decimal points. A few commands logically require the use of integers, but MED-PC automatically converts numbers to integer format, where necessary, by rounding them to the nearest whole number. For example, "ON 1.9" or "ON 2.1" are illogical, but will not cause difficulties because MED-PC will automatically convert both to "ON 2". The only place where proper use of integers is required is in declaring constants and in numbering state sets and states.

Constants:

Constants are a convenient means for substituting words for frequently used integers. Constants must be declared prior to the first state set and may be up to 55 characters in length. They must be preceded by a caret "^" and the first character must be a letter followed by any mix of letters and numbers. Spaces are ignored. An example declaring "^Feeder" follows:

```
^Feeder = 1
S.S.1,
S1,
  Input: ON ^Feeder ---> S2

S2,
  2": OFF ^Feeder ---> S1
```

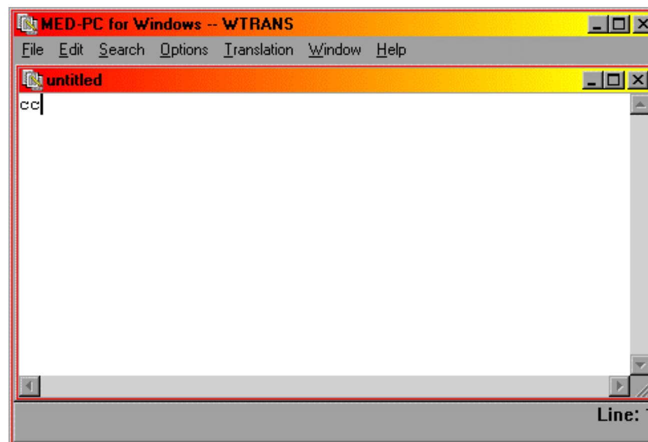
Constants must be declared as having an integer value, and time may not be assigned to a constant. For example, "^Feeder = 1.1" and "^FeederDur = 2”" are illegal. As constants are represented as integer (whole) numbers, it is illegal to attempt to assign the value of a variable to constant during program execution. There is no limit to the number of constants that may be in a single procedure, but values may be assigned to a constant are restricted to a range from -32768 to 32767.

The use of constants cannot be emphasized enough. Constants tremendously improve the readability of a procedure, and can substantially reduce debugging time. They also greatly ease the difficulty associated with understanding a procedure written by someone else or simply written years earlier. A very good practice is to define and use constants to refer to all inputs and outputs.

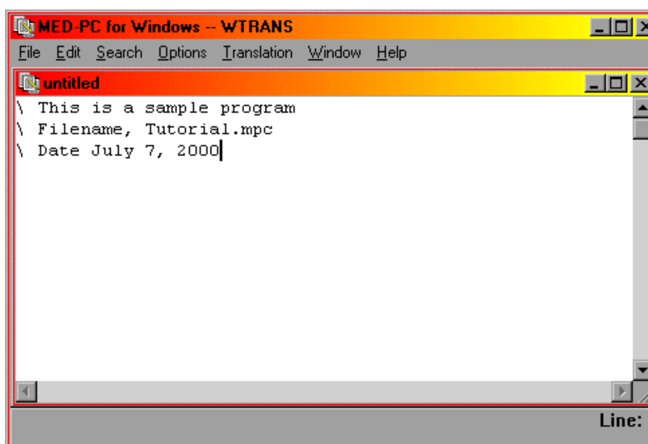
Tutorial 1: Writing your first program

Now you have the basic terminology and concepts down to write a simple program. This will replace the vague notions of "input," Output," and "Next" from the previous sections and replace them with concrete example of code. In this exercise you will learn how to arrange State Sets, States and Statements as well as learn the proper use of Statements, Constants, Inputs, and Outputs. For the example, we will assume that your operant chamber is equipped with a house light, although any output device can be used.

The first step is to open TRANS for Windows®. Scrolling the mouse to the menu bar, first click "File" and then click "New." [2]

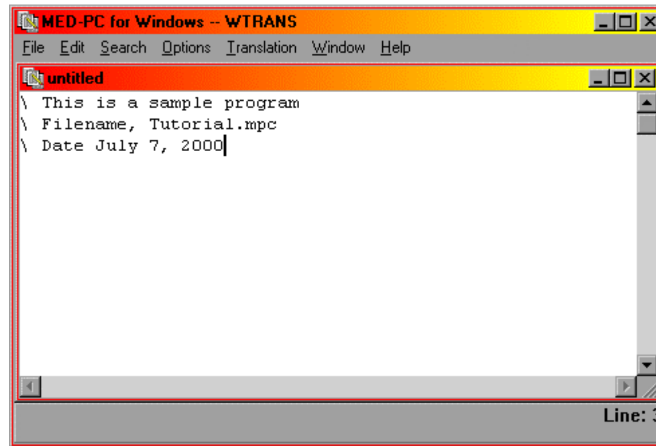


Second, we will type in our comments. Remember, it does not matter what is said in the comment section, it is only there for your convenience.

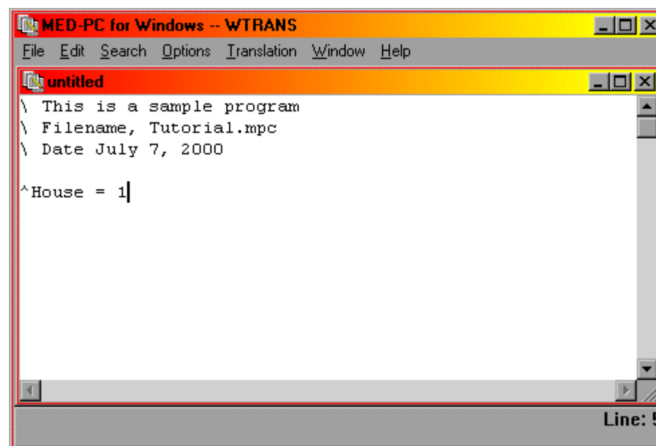


---

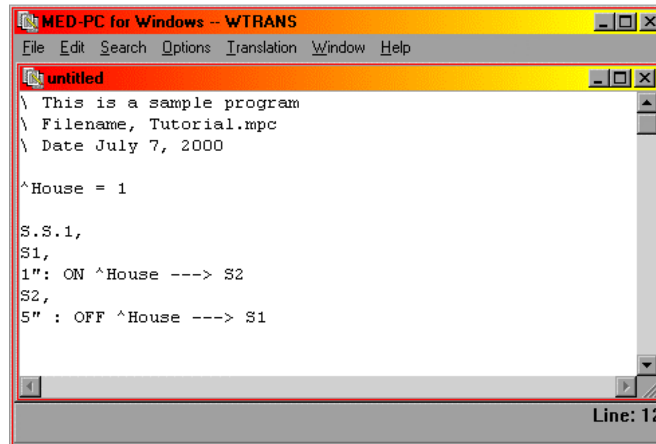
[2] Please note that any ASCII text editor may be used to type the initial code. If a text editor other than the one supplied with TRANS for Windows is used, however, you must save the text as unformatted ASCII or DOS text and it must be saved with the extension *.MPC (where * is your filename.).



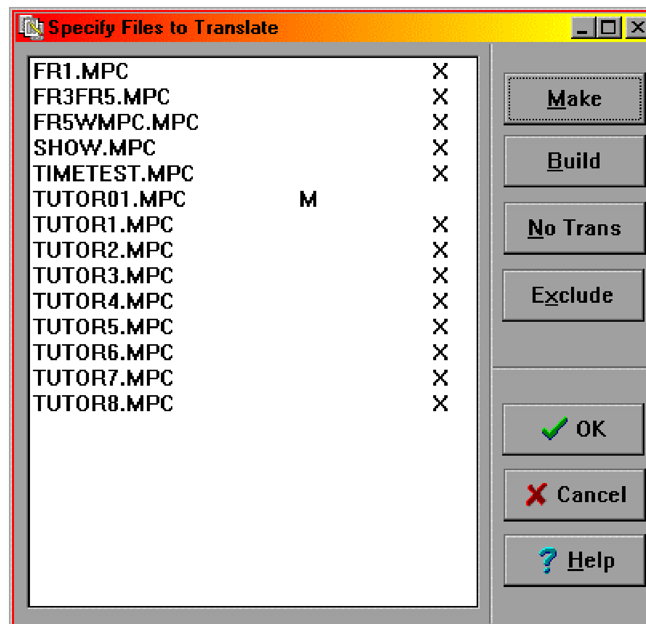
Next, we will define our constants. This is a simple program with only one input, time, and one output, the house light. Therefore, we will define one constant for the house light and we will call it "House".



As previously mentioned, time will be our input. In MedState Notion, we do **not** write out minutes or seconds. Instead, seconds are represented by a double quotation mark **(")** and minutes are represented by single quotation marks, **(')**. In this example, our first input will be one second (1") and the second input will be five seconds (5"):



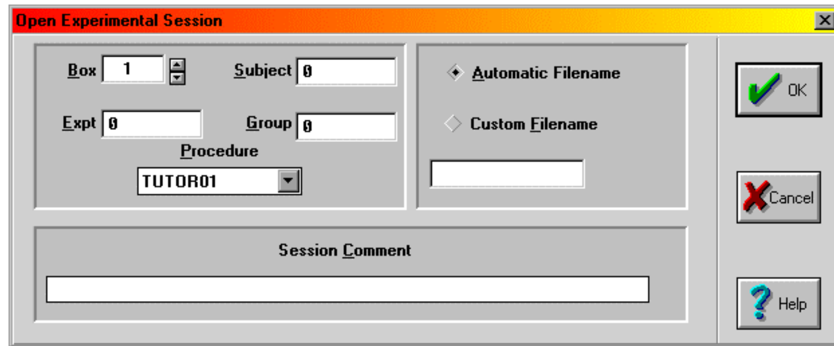
Save this file as Tutor01.mpc in your C:\WMPC\MPC file. Once you are satisfied the program is saved, scroll the mouse across the menu bar, click "Translation" and follow that up by clicking "Translate and Compile [3]." Highlight the filename "Tutor01.mpc" with your mouse and click MAKE. There should now me a letter M a tab space or two away from the file name, now click "OK." Your program should now automatically translate (Parse) and compile. When it is done, close TRANS for Windows® and open MED-PC® for Windows.



Scrolling your mouse to the menu bar, click first on "File" and then on "Open Session." Open Tutor01.mpc.

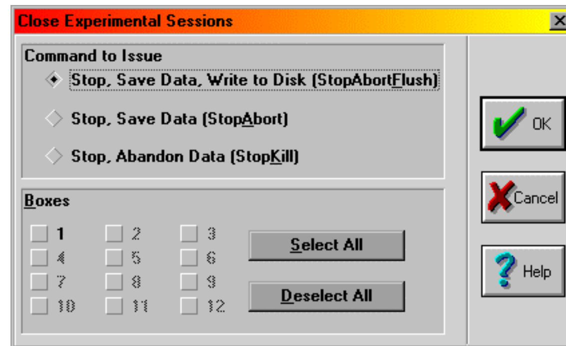
---

[3] Note: If you chose to use another text editor, save your file and close your text editor. Open your file in TRANS for Windows.



After one second, your house light should come on for five seconds, turn itself off for one second, and repeat this cycle until the session is closed.

To close the session, scroll and click once again to "File" on the menu bar and click on "Close Sessions." A pop up window should now appear.



Check the button next to Box 1 and Check the Button "Stop Kill." Note that the light turning on and off continues as you are in this window because the close command does not get sent until you click "OK."

Congratulations, you just wrote, ran, and closed your first program in MEDSTATE using MED-PC for Windows!

Chapter Three:
An Introduction to #R, SX, ADD, and SHOW Commands

In the previous chapter, we used time as our only input. Although time is used quite often as inputs, what may be of more interest to us as researchers is the input from our test animal on a response lever, lickometer, nose poke, etc. Also, remember back to what was being displayed on the MED-PC window, as you ran your first program, not much. This chapter will explain how to write code for the recording of mechanical inputs as well as how to display the information on the screen.

#R:

#R is, in the simplest terms, the code for the response of a test animal on a MED Associates input device (e.g. a lever). In order for #R to have any meaning in a program, you must specify what device the response is on as well as the number of times the response must happen. So the syntax is:

```
[Number of times]#R[Device that is collecting input]: OUTPUT ---> NEXT
```

So real code may look like:

```
5#R^LeftLever: ---> S4
```

Which means, "After five presses of the left lever, make the transition to State 4."

Or:

```
#R^RightLever: ON ^Pellet ---> S2
```

Which means "After one press of the Right Lever (MedState Notation has a default of one for #R), turn on the pellet dispenser and make the transition to S2.

Null Transition (SX):

In the aforementioned example, a transition was made to S2 after the pellet dispenser was turned on, but sometimes we do not want to make a transition to another state, it would be better to "go nowhere." Well MedState Notation can do this with a command we call SX, which is known as the null transition. The significance of this command will be shown shortly, but in code it would come after the transition:

```
INPUT: OUTPUT ---> SX
```

ADD:

As the name suggests, ADD is a mathematical command that will increment a variable by one. It is an output command, so it will always follow the colon in our code. Its syntax is:

```
INPUT: ADD X ---> NEXT
```

Where X = the variable to which the value 1 will be added.

Real code may look like this:

```
S1,
  1": ADD C ---> S2
```

In this example, after one second, the value one will be added to the variable C and then the transition will be made to S2.

SHOW:

In the program you wrote at the end of Chapter 2, you knew it was running by watching the light come on and off. As explained thus far, you would not know your program was running when using an ADD command because there is no feedback associated with it. This is why we have the SHOW command. When MED-PC programs are running, lines 2-13 of the screen may be used to display data for each active box. MED-PC programs may display information in this space in each of sixty positions (numbered 1 - 60). The syntax is:

```
INPUT: OUTPUT; SHOW P,Label,X ---> NEXT
```

Where P = Position 1-60 (must be defined), Label is a user-defined name for that position 1-60 that cannot be more than six characters long and must begin with a letter (the other five characters may be alpha-numeric), and X is the variable value listed in position 1-60.

Real code may look like this:

```
#R2: ADD A; SHOW 1,CENKEY,A ---> SX
```

Where after one response on input 2, we will add one to the variable A and finally the value of variable A will be displayed on the screen in position 1 (and to the left of the value will be the label CENKEY) before making the null transition.

Tutorial 2: Expanding your first program

In this exercise, we are going to expand on the program you wrote in the first tutorial. Whether you want to open Tutor01.mpc and make these changes and save as Tutor02.mpc or just start fresh is up to you. The goal of this program will be to have a count appear on the screen every time the left lever is pushed.

Once again, open your text editor (TRANS for Windows) and type in the following:

```
\This is a sample program
\Filename, Tutor02.mpc
\Date July 7, 2000

^House = 1
^LeftLever = 1

S.S.1,
S1,
  .01": ON ^House ---> S2
```

Note that the house light is an output whereas the left lever is an input. That is why both constants can be defined as 1. If there was anything in this program thus far that you did not understand, refer back to Chapter Two.

Next we will want to add the code for the responses, the count, and the display. In order to do this, we must add a new State within State Set 1.

```
\This is a sample program
\Filename, Tutor02.mpc
\Date July 7, 2000

^House = 1
^LeftLever = 1

S.S.1,
S1,
  .01": ON ^House ---> S2

S2,
  #R^LeftLever: ADD C; SHOW 1,COUNT,C ---> SX
```

And just like that, your program is now ready to be saved as Tutor02.mpc in the C:\WMPC\MPC directory.

Once you are satisfied the program is saved, follow the same procedure as before to translate and compile this program and then open it in MED-PC. If you do not remember how to do this, refer back to chapter two's tutorial.

If the program is running, the house light should turn immediately after loading the program. Now reach into the box and click the left lever. Notice how the count increments on the screen.

If it is not going up geometrically (…11, 12, 13, 14, 15…), but instead sporadically (11, 16, 18, 19, 22), do not be alarmed. The screen update is a low priority function. If the responses are rapid, the computer is keeping an accurate count of the data, but the screen is only updated when the system gets a chance.

Congratulations, you successfully wrote another program. You may end your session in the same manner as Tutor01.mpc.

Chapter Four:
Controlling the Beginning and End of a Program

Thus far, all programs that we have wrote have begun to run the second they were loaded. For our purposes, this was fine; there was no reason for them wait before running. This is usually not the case, however. Your experiment may require you to load more than one box and have them run simultaneously or perhaps you want to have the program all ready to go before loading your test subject in the chamber. In either case, starting the program upon loading is not what we would want to do. This chapter will deal with how to avoid that problem, as well as how to have your program stop without having to issue the stop session command.

#START:

As already stated, execution begins as soon as the procedure was loaded in our earlier programs. The #START command will give us the ability to load a procedure but hold procedure initiation until a signal is given by the experimenter. This is especially useful when loading several boxes because this enables the experimenter to place multiple subjects in experimental chambers and then start their sessions simultaneously. #START is an input command so the syntax is:

```
#START: OUTPUT ---> NEXT
```

Or real code may look like:

```
#START: ON ^HOUSE ---> S2
```

This means, "Wait until a start command has been issued and when it has, turn on the house light and make the transition to State 2."

We will get into what it means to issue a start command in the tutorial.

STOPABORT and STOPKILL:

These two commands cause the program that is running to immediately stop executing. Any outputs currently turned on get shut off immediately (i.e., whether the program is in the middle of a procedure or not, everything stops). In addition, the box's status lines on the monitor are cleared. The difference between STOPABORT and STOPKILL is that data collected up to the STOPABORT command can still be salvaged by saving and/or printing it (i.e., it is still in memory) whereas STOPKILL wipes the data from the memory. These commands are special transitions, so their syntax is:

```
INPUT: OUTPUT ---> STOPABORT
```

Or

```
INPUT: OUTPUT ---> STOPKILL
```

Real code may look like this:

```
2': ---> STOPABORT
```

Or

```
2': ---> STOPKILL
```

So this is saying after 2 minutes make the transition to stop, but leave the data in memory (or stop and wipe the memory clean).

STOPABORTFLUSH:

Like STOPABORT, STOPABORTFLUSH is a special transition that turns off all outputs and stops procedure execution. Instead of keeping the data in memory, however, STOPABORTFLUSH will save the data to the hard drive and then wipe the memory clean. The syntax will be similar to STOPABORT:

```
INPUT: OUTPUT ---> STOPABORTFLUSH
```

Or real code may look like this:

```
60': ---> STOPABORTFLUSH
```

Where after 60 minutes, the program will stop, the box status will clear, the data will be saved to disk and the memory will be wiped clean.

Multiple Commands:

So far we have been following the format, one INPUT, OUTPUT, AND NEXT per line. Since there are cases where this is not practical (e.g., If you want to ADD to a variable and simultaneously SHOW the variable on the screen), MedState Notation allows for the stringing together of multiple commands. In order to do this, semicolons are used to separate the parameters of a command from the following command. The syntax would be:

```
INPUT: OUTPUT#1; OUTPUT#2 ---> NEXT
```

Or real code may look like this:

```
#R^LeftLever: ADD C; SHOW 1,COUNT,C ---> SX
```

Tutorial 3: Expanding your last program to control itself

In this exercise, we are going to expand on the program you wrote in the second tutorial. The goal of this program will be to demonstrate how to issue a start command and have your program stop on its own. You will also learn what you can do once the program stops.

Once again, open your text editor (TRANS for Windows) and type in the following:

```
\This is a sample program
\Filename, Tutor03.mpc
\Date July 7, 2000

^House = 1
^LeftLever = 1

S.S.1,
S1,
```

Next we want to add the code for the responses, the count, and the display. In order to do this, we must add a new State within State Set 1.

```
\This is a sample program
\Filename, Tutor03.mpc
\Date July 7, 2000

^House = 1
^LeftLever = 1

S.S.1,
S1,
  <This we will fill in>

S2,
  #R^LeftLever: ADD C; SHOW 1,COUNT,C ---> SX
```

Now we need to add our start command, so under State Set 1, State 1 type:

```
#START: ON ^House ---> S2
```

We need to add a new State Set to have our program stop on its own, so type the following at the bottom of the new program:

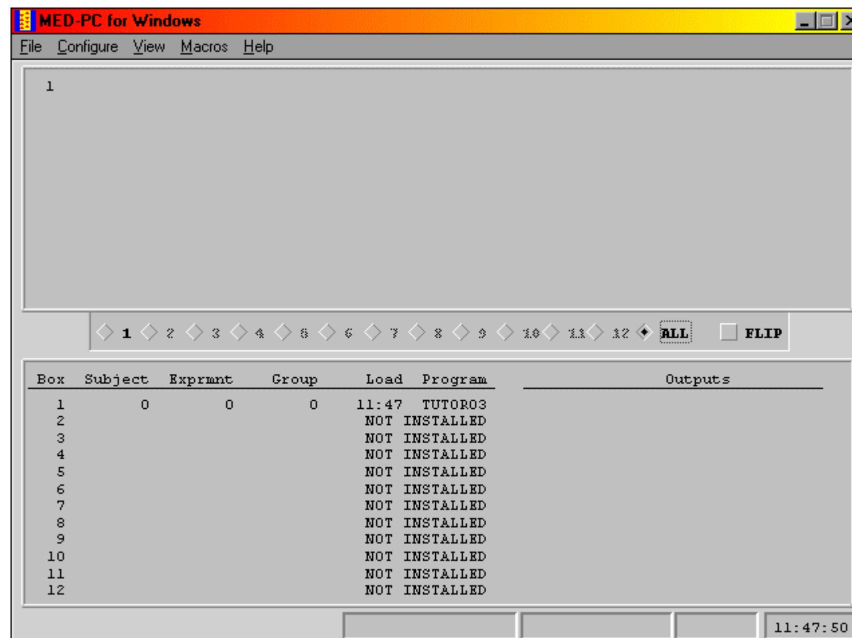
```
S.S.2,
S1,
  #START: ---> S2

S2,
  1': ---> STOPABORT
```

So your final product should look like this:

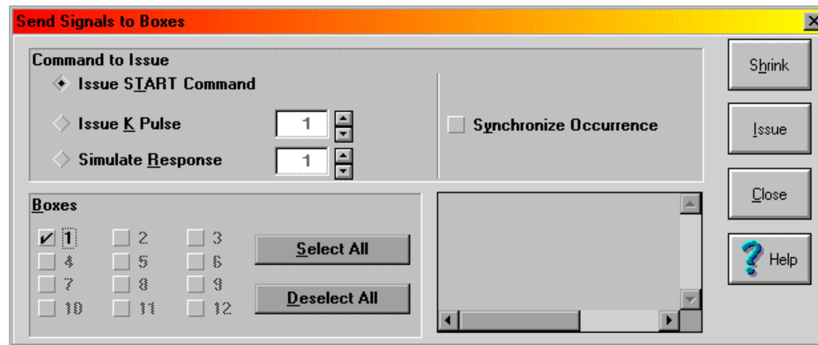
```
\This is a sample program
\Filename, Tutor03.mpc
\Date July 7, 2000
^House = 1
^LeftLever = 1

S.S.1,
S1,
  #START: ON ^House ---> S2

S2,
  #R^LeftLever: ADD C; SHOW 1,COUNT,C ---> SX


S.S.2,
S1,
  #START: ---> S2

S2,
  1': ---> STOPABORT
```

And just like that, your program is now ready to be saved as Tutor03.mpc in your C:\WMPC\MPC directory.

Once again, follow the same procedure as before to translate and compile this program and then open it in MED-PC. Notice how, unlike before, the house light is not on. But look at the bottom window -- it shows that the program "Tutor3" was loaded at xx:xx (your computer clocks current time). This shows that the box was indeed loaded, and is now awaiting your start command.



So let us issue the start command. Scroll your mouse to the menu bar and click first on configure and then on signals. A window will pop up giving you more options.



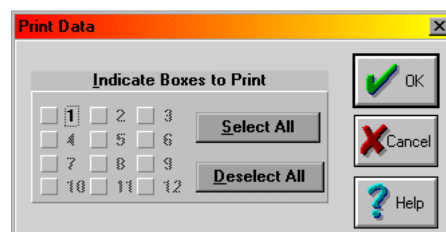
The "Issue start command" button is already highlighted, so all you should need to do is click on the button next to "BOX 1." Once both are selected (represented by black dots), press the ISSUE button. Your program is now running.

Like you did in the previous tutorial, press the left lever a couple times to get a few counts on the screen. After one minute, the house light should go off, the counter will no longer go up with subsequent lever pushes, and the information next to box 1 should be gone and the word, "Closed" should appear. This demonstrates that your program was successfully STOPABORTed.

Keep in mind, your data is still in memory, and MED-PC knows this. To test this, try to close MED-PC. You will get an error window with the following message: "MED PC HAS UNFINISHED BUSINESS"

Choose "cancel."

Going back to file, select print and check BOX 1 and then click OK.



You should now have a print out of your data from that "experiment." It is up to you if you want to save this data or close without saving.

Congratulations, you have now written three programs.

Chapter Five:

Creating a Program for an FR Schedule
(An Introduction to Z-pulses and Adding a Counter to Inputs)

Until the last chapter, all of our programs have only had one State Set, and in the last chapter there was no need for our two state sets to communicate with one another. MedState Notation utilizes Z-pulses to communicate between state sets.

Z-pulses (#Z)

It is often convenient to break procedures into multiple state sets. Indeed, procedures composed of multiple state sets are more readable and easier to modify than single state set procedures and Z-pulses provide a convenient means for communicating among state sets. Let us say that the left key's red stimulus is flashed on off whenever the FR-5 contingency has not been satisfied but is turned off during feeder operation. You may be able to write a program that had all of this in one State Set, but it would be confusing and have the potential to be prone to programming errors. It would be easier to program the flasher as a separate state set and then turn it off and on as needed (i.e., when the test animal has or has not met the conditions you define).

Like State Sets and States, Z-pulses must be numbered but the highest Z-pulse may not be greater than 32.[4] Unlike any of the other commands which fit nicely in our INPUT: OUTPUT ---> NEXT format as either an INPUT, an OUTPUT or a NEXT, Z-pulses are unique in that each Z-pulse acts as either an input or an output. Although this concept may seem confusing at first, if you think about the role that the Z-pulse plays it makes sense; it communicates between two state sets. The syntax of the Z-pulse is:

```
S.S.1,
S1,
  INPUT: Z N ---> NEXT


S.S.2,
S1,
  #ZN: OUTPUT ---> NEXT
```

Where N = an integer between one and thirty-two and is the same in both examples. Also note that when used as an output, the syntax is **ZN** but when used as an input, the syntax is **#ZN**.

---

[4] Also like State Sets and States, the numbering of Z-pulses is arbitrary in the sense that they do not have to be sequential – they are processed in the order they are read. It is recommended, however, that you keep the numbers sequential to minimize the potential confusion.

In real code, it may look more like this:

```
S.S.1,
S1,
  #START: ON ^HouseLight; Z1 ---> S2


S.S.2,
S1,
  #Z1 ---> S2
```

Rules For Comments Revisited:

In the second chapter the idea of comments was introduced and we have used them in every program we have written, at the beginning of each program, before we wrote any real code. Comments can also be placed at the END of a line code (Once again, comments may not occur in the middle of a statement). This tactic will be used from here on out in tutorials to explain why things are written the way they are or placed where they are (please note that it will be up to you whether or not you type in these comments in the tutorials – they are there for your benefit only). The syntax is demonstrated below:

```
S1,
  Input: Output ---> Next    \Comment
```

Tutorial 4: Writing an FR-5 Program

In this exercise, we are going to use parts of the program you wrote for the last tutorial. The goal of this tutorial will be to write a program that works on a Fixed Ratio Schedule.

Once again, open your text editor (TRANS for Windows) and type in the following:

```
\This is an FR-5
\Filename, Tutor04.mpc
\Date July 7, 2000

\This section is for inputs
^LeftLever = 1

\This section is for outputs
^House = 1
^Reward = 2    \In this code, this is a pellet dispenser.

S.S.1,    \Main control logic for "FR"
S1,
  #START: ON ^House ---> S2
```

Next we will want to add the code for the responses (remember, this is an FR-5) as well as a means of keeping count of the responses in another State Set. In order to do this, we must add a new State with in State Set 1.

```
S2,
  5#R^LeftLever: ON ^Reward; Z1 ---> SX
```

The Z-pulse (Z1) is what will let us record our rewards in another state set, which we will program later. Now we will program our response count and set it up to display on the screen:

```
S.S.2,    \This is the state set that contains the response
          \count and display
S1,
  #Start: SHOW 1,RESP,A ---> S2
  \This will now put label "RESP"
  \and its value "A" on screen
  \until start command issued.

S2,
  #R^LeftLever: ADD A; SHOW 1,RESP,A ---> SX
```

Now it is time to insert the code for that reward counter and timer. In order to do this, we will have to use the Z-pulse generated in State Set 1. Note how the Z-pulse has a # sign in front of it. This demonstrates that it is an input, as opposed to an output (as it was in State Set 1):

```
S.S.3,    \Reward Counter and Timer
S1,
  #Z1: ADD B; SHOW 2,REWARD,B ---> S2

S2,
  .05": OFF ^Reward ---> S1
```

The final bit of code we must write is for the session timer. As you can tell, it is identical to the session timer used in the previous tutorial.

```
S.S.4,    \Session Timer
S1,
  #START: ---> S2

S2,
  1': ---> STOPABORT
```

Since that was the last state set, the final product looks like this:

```
\This is an FR-5
\Filename, Tutor04.mpc
\Date July 7, 2000

\This section is for inputs
^LeftLever = 1

\This section is for outputs
^House = 1
^Reward = 2    \In this code, this is a pellet dispenser.

S.S.1,    \Main control logic for "FR"
S1,
  #START: ON ^House ---> S2

S2,
  5#R^LeftLever: ON ^Reward; Z1 ---> SX


S.S.2,    \This is the state set that contains the response
          \count and display
S1,
  #START: SHOW 1,RESP,A ---> S2

S2,
  #R^LeftLever: ADD A; SHOW 1,RESP,A ---> SX


S.S.3,    \Reward Timer, count, and display
S1,
  #Z1: ADD B; SHOW 2,REWARD,B ---> S2

S2,
  .05": OFF ^Reward ---> S1


S.S.4,    \Session Timer
S1,
  #START: ---> S2

S2,
  1': ---> STOPABORT
```

And just like that, your program is now ready to be saved as Tutor04.mpc in your C:\WMPC\MPC directory.

Once again, follow the same procedure as before to translate and compile this program and then open it in MED-PC. The bottom window should show that the program "Tutor4" was loaded at xx:xx (your computer clocks current time). Now issue the start command as you have done in the past. When you have issued the start command, hit the left lever repeatedly to get responses and reward counts on the screen. When one minute has passed and the program has shut down, the data is hanging in limbo waiting for your next move. Do with the data what you please (i.e., save, print, or erase). This is a good opportunity for you to test your knowledge.

You are on your way to becoming an expert user!

Chapter Six:
Establishing Default Values for Variables and Using a Variable Time Input (An Introduction to the SET and #T Commands)

SET:

SET is used to perform any of four basic mathematical operations involving two or more operands [5]. The four operators permitted are multiplication (*), division (/), addition (+), and subtractions (-). Although always outputs, two forms of this command are possible as indicated by syntax A and syntax B.

Syntax A:
INPUT: SET P1 = P2 Operator P3 ---> NEXT

Syntax B:
INPUT: SET P1 = P2 ---> NEXT

Where: P1 = variable or array element, P2 and P3 = number, variable, or array element, and Operator = a mathematical operation (e.g., *, /, +, or -).

It is important to point out that the stringing of elements with in the program is permissible (i.e., P2 or P3 may be followed by " or ' to assign a time value to a variable) with each operation separated by a comma. Variables may also be set to seconds or minutes. Assigning a new value to a constant, however, is not permissible.

Real code may look like this:

```
1': SET A = 5 * A, B = C(K) ---> SX
#R3: SET A = (5 * A) + B + C ---> SX
#START: SET A = A * 1"
```

One last side note on the set command, in the past, complicated math expressions had to be broken into pieces. MedState Notation has now been extended so that complex expressions (e.g., 1 + [(2 * 10) / 4] - 3) may now be written directly (e.g., SET A = 1 + ((2 * 10) / 4) - 3).

Variable Time Inputs (#T):

Time may be explicitly defined in terms of minutes (10' = ten minutes) or seconds with a whole or decimal number (3.5" = three and one half seconds). Variable time inputs using the #T command are also possible. Regardless if the time values are explicit or variable, time always serves as an input in MedState Notation. When it is desirable to change the value of a time variable, #T is preceded by a variable containing a specified amount of time. The syntax will be:

---

[5] Any mathematical function provided by Turbo Pascal can also be inserted within a MedState Notation statement using In-Line Pascal.

```
X#T: OUTPUT ---> NEXT
```

Where X is a predefined variable; in this example it is set to a value of 1:

```
S.S.1,
S1,
  #START: ON 1; SET X = 1" ---> S2

S2,
  X#T: OFF 1 ---> S1
```

Please note, as with explicit time values, only one time command per state may be present, so the following example of code is illegal:

```
S1,
  X#T: ---> SX
  1": ---> SX
```

Tutorial 5: Creating an FI Schedule

Start by opening Tutor04.mpc and make the following changes (changes noted in bold and appropriate comments are made off to side):

```
\This is an FI
\Filename, Tutor05.mpc
\Date July 7, 2000

\This section is for inputs
^LeftLever = 1

\This section is for outputs
^House = 1
^Reward = 2    \In this code, this is a pellet dispenser.

S.S.1,    \Main control logic for "FI"
S2,                                                  \Changed S1 to S2
  #START: ON ^House; <WILL BE ADDING CODE HERE> ---> S3

S4,                                                  \Changed S2 to S4
  #R^LeftLever: ON ^Reward; Z1 ---> SX               \DELETE 5 BEFORE #R


S.S.2,
S1,
   #START: SHOW 2,RESP,A ---> S2                     \WAS SHOW 1

S2,
  #R^LeftLever: ADD A; SHOW 2,RESP,A --->SX


S.S.3,
S1,
  #Z1: ADD B; SHOW 3,REWARD,B ---> S2                \WAS SHOW 2

S2,
  .05": OFF ^Reward ---> S1


S.S.4,
S1,
  #START: ---> S2

S2,
  1': ---> STOPABORT
```

Next we will add our "SET" code. The variable we are going to set is "X" which, in this program, will be our fixed interval. We are going to default it to 10, but later in this tutorial we will see how to change this interval without changing the code. All of the "SET" code will be inserted into State Set 1:

```
S1,
  .01": SET X = 10 ---> S2

S2,
  #START: ON ^House; SET X = X*1" ---> S3
  \ Converts time into WMPC clock ticks
  \ (Interrupts -- see User's Manual for additional
  \ information on runtime system).
  1": SHOW 1,FI =,X ---> SX
```

Next add the time command #T with Variable X as State 3 of State Set 1:

```
S3,
  X#T: ---> S4
```

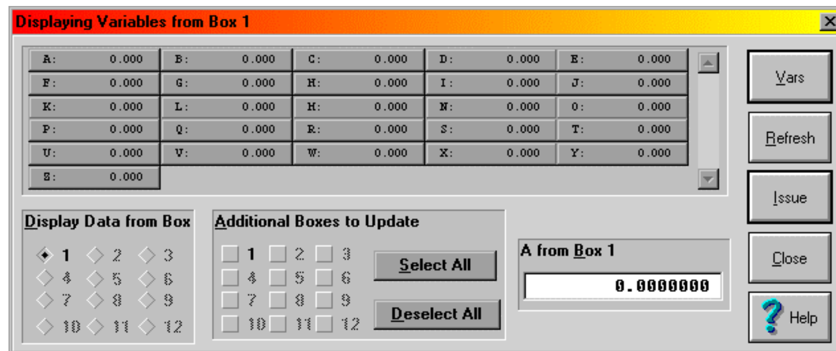
The final product should look like this:

```
\This is an FI
\Filename, Tutor05.mpc
\Date July 7, 2000

\This section is for inputs
^LeftLever = 1

\This section is for outputs
^House = 1
^Reward = 2    \In this code, this is a pellet dispenser.

S.S.1,    \Main control logic for "FI"
S1,
  .01": SET X = 10 ---> S2

S2,
  #START: ON ^House; SET X = X*1" ---> S3
  1": SHOW 1,FI =,X ---> SX

S3,
  X#T: ---> S4

S4,
  #R^LeftLever: ON ^Reward; Z1 ---> S3


S.S.2,    \This is the state set that contains the reward count
          \and display
S1,
  #START: SHOW 2,RESP,A ---> S2

S2,
  #R^LeftLever: ADD A; SHOW 2,RESP,A ---> SX


S.S.3,    \Reward Timer
S1,
  #Z1: ADD B; SHOW 3,REWARD,B ---> S2
S2,
  .05": OFF ^Reward ---> S1
```

```
S.S.4,    \Session Timer
S1,
  #START: ---> S2

S2,
  1': ---> STOPABORT
```

Save this file as Tutor05.mps and follow the same procedure as before to translate and compile this program and then open it in MED-PC, load the file, issue the start command as you have done in the past, and hit the left lever repeatedly to get responses and reward counts on the screen. As you can see, you are clearly on an FI-10 schedule. When one minute has passed and the program has shut down, the data is hanging in limbo waiting for your next move. Do with the data what you please, but DO NOT exit WMPC. Instead, reload the box – we are going to change this to an FI-15.

A "Change Variables" screen may be brought up by scrolling the mouse first to the "Configure" option of the menu bar, clicking once, and then clicking on "Changing Variables."



Changing the value of any selected variable field changes the variable data for the displayed box. You can change all boxes if you click "Select All" or only some boxes by clicking the appropriate number(s) in the "Additional Boxes to Update" section of the window. For our purposes, we only want to change one variable (the interval) on one box (Box 1). If you look back at the code you wrote for this program, the variable "X" is the interval value. So click in the text box next to the letter "X." In the lower, right hand corner of the "Change Variable" window, there is a text box whose title is now "X from Box 1," and whose default value is 10. To change this program to an FI-15, replace 10 with 15 and click "Issue." You now have an FI-15. You can tell this by looking at the runtime screen. Note how the FI value displayed is now 15. You can run the program if you would like, or you can close it now.

From the Window's Desktop, reopen WMPC and reload "Tutor05." Now look at the run time screen. Note how it reads FI = 10. This is because the "Change Variables" screen does not change the code, only the value of the variable for the procedure currently being run. Once you close WMPC, the change goes away. You can change it back upon reopening the WMPC or even change it multiple times in one session, depending on how the code is written. In the current example, changes made after the #START command is issued would result in an error unless the value changed is in "MED clock ticks."

Chapter Seven:
Decisions, Decisions, Decisions
(Introducing the "IF" Statement)

Until this point, the programs that have been written have been very straightforward. They have all followed a pattern of, "do one thing until completed, then another, then another until I either get tired of watching (e.g., the house light blinking on and off) or time is up (e.g., tutorial 5)." By utilizing the "IF" command we are able to have programs come to a proverbial fork in the road and the path they take is contingent on whether or not a criterion you have established has been met. There are many variations to the IF command and this chapter will deal with three of them. As a result, there will be three versions of the tutorial at the end of the chapter so that you can see how they would all work in the code.

An overview of "IF":

IF is an output command that compares the values of two numeric parameters, a numeric parameter and a variable, or two variables. The basic syntax of "IF" regardless of function, is [6]:

```
INPUT: IF P1 Operator P2 [@Label1, @Label2]
          @Label1: Output ---> NEXT 1
          @Label2: Output ---> NEXT 2
```

Where: "P1 and P2" are constants, numbers, variables, etc.; " Operator" is one of six comparisons operators that are permitted: Equals (=), Less Than (<), Less Than or Equal To (<=), Greater Than (>), Greater Than or Equal To (>=), or Not Equal To (<>); and @Label is a condition that must be met (e.g., true or false). Note, the @ must be present before the "Label" but the label itself is purely subjective.

IF as a session timer:

We have been using a crude version of a session time for a few tutorials now. The set up has been after one minute, stop everything no matter what. Since we were not running very complex programs, you have probably not noted a problem with this. If there were a lot of things going on in the program, it would be possible for the screen data not to agree with the saved data (the saved data would be higher and correct, but the screen may not have time to update) or the program may stop in the middle of an event (like issuing a reward). Neither of these are ideal situations.

---

[6] Please note, there are three syntaxes that can be used to write an IF statement. This chapter will only show how to use the most complete syntax that can be used in any situation. As time goes on, and you become more comfortable with programming in MedState Notation, you may choose to look in Appendix A: MEDSTATE NOTATION COMMANDS for examples of how to use the other, abbreviated, syntaxes.

Assume that your experiment is running for sixty minutes, real code may look like this:

```
S.S.5,
S1,
  1": ADD N; IF N/60 >= M [@TrueEnd, @FalseContinue]
                @End: Z5 ---> S2
                @Cont: ---> SX

S2,
  3": ---> STOPABORT
```

What this is doing is adding the variable N every second and then converting the new value N to minutes. Since your session timer (represented by variable M) is set for 1 hour, or sixty minutes, this IF statement is set to stop the program at an hour or any fraction above it. If the session has been running for less than an hour, the system waits (coded for by @Cont: --->SX). When an hour has passed, the program transitions to S2 where it waits three second before shutting down (therefore the screen can be updated, the reward can be given, etc.). A Z-pulse has been added that can be used where a function is terminated immediately (e.g., a response contingent statement or counter).

Nested IF commands:

IF statements are not limited to only one set of options, they can also be nested. The syntax is nearly the same as a non-nested if, with the exception being that the nested commands must be organized sequentially:

```
1": IF A >= X [@FirstTrue, @FirstFalse]
       @FirstTrue: IF B >= X [@SecondTrue, @SecondFalse]
                      @SecondTrue: IF C >= X [@ThirdTrue, @ThirdFalse]
                                      @ThirdTrue: ---> S2
                                      @ThirdFalse: ---> S3
                      @SecondFalse: ---> S3
       @FirstFalse: ---> S3
```

In the above example, all three variables (A, B, and C) must be greater than or equal to X for the statement to transition to S2. Any False outcome results in a transition to S3.

Compound IF commands:

IF statements also may be constructed so that several logical conditions are evaluated in a single expression. This may be accomplished by placing each set of logical criteria in parentheses and connecting each set with AND, OR, NOT, AND NOT, or OR NOT. Parentheses must be used to denote the order in which expressions are evaluated if multiple expressions are strung together (note that this is like the way that parentheses control execution of algebraic expressions in SET statements). The syntax would look like this:

```
INPUT: IF (A = 1) AND (B = 2) [@True, @False]
          @True: ---> S2
          @False: ---> SX
```

Real Code may look like this:

```
S.S.5,
S1,
  1": IF (R = 100) OR (M = 60) [@True, @False]
         @True: ---> S2
         @False: ---> SX

S2,
  3": ---> STOPABORT
```

Tutorial 6A: Using A Single "IF" Command as a Session Timer

At this point you know how to write/change your program, translate/compile it, load it, change the variables, and run it. For the second two uses of the "IF" command, only the final product is going to be given to you with the changes from Tutor06A.mpc shown in bold, although a short explanation to why changes were made will be given for Tutor6b.mpc. Write and test both of them and if you have any problems, refer to earlier tutorials.

The first step is to open Tutor04.mpc and make the following changes noted in bold:

```
\This is an FR schedule
\Filename, Tutor06A.mpc
\Date July 7, 2000

\This section is for inputs
^LeftLever = 1

\This section is for outputs
^House = 1
^Reward = 2    \In this code, this is a pellet dispenser.

\DEFINED VARIABLES
\ A = NUMBER OF RESPONSES
\ B = NUMBER OF REWARDS
\ M = MINUTES
\ X = FIXED RATIO
\ N = SESSION TIMER


S.S.1,    \main control logic for "FR"
S1,
  1": SET M = 1; SET X = 5 ---> S2

S2,
  #START: ON ^House ---> S3

S3,
  X#R^LeftLever: ON ^Reward; Z1 ---> SX


S.S.2,
S1,
  #START: SHOW 2,RESP,A ---> S2

S2,
  #R^LeftLever: ADD A; SHOW 2,RESP,A ---> SX


S.S.3,
S1,
  #Z1: ADD B; SHOW 3,REWARD,B ---> S2

S2,
  .05": OFF ^Reward ---> S1
```

A few things are worth pointing out. You have changed the position of the displays for the responses and the reward counters by shifting them over one. This should tip you off that we are going to add another counter before these "preexisting" ones before we are done. The other thing we have done is added a set of statements in the beginning of the program that "define" our constants. Since they are statements preceded by a backslash, they are not part of the heart of the program. They are only there for our convenience. It is a wise thing to put the definitions in because we now have more variables that we can change the value of (and even more will be able to be changed in the next two tutorials). As it stands now, once this program is translated and compiled, you will be able to change M (duration of the program) and X (the fixed ratio number).

Now we need to add our session timer, which will be our state set 4. The code is:

```
S.S.4,    \Session timer
S1,
  #START: SHOW 1,Sess_n,N ---> S2

S2,
  1": ADD N; SHOW 1,Sess_n,N/60;
      IF N/60 >= M [@True, @False]
         @True: ---> S3     \Therefore, when the session timer
                            \>= M, time to stop
         @False: ---> SX    \But here if session timer < M, go
                            \nowhere

S3,
  3": ---> STOPABORT
```

Your program is ready to be saved (as Tutor06A.mpc), translated, and compiled. When you open WMPC to test it, run it first, as is. After seeing that it times out after a minute, but acts as a fr-5 when it is running, reload the box with Tutor06A and change variables X to 10 and M to 1.5 before issuing the start command. Notice now how it is running as a FR-10 for a minute and a half.

Tutor06B.mpc

We are doing a couple of interesting things in this program. As the chapter would lead you to believe, the primary purpose of this program is to see how a nested "IF" statement works. State 2 of state set 4 contains our nested "IF" statement. In order to make it work, we had to revisit a couple familiar topics. First, we needed to SET a variable back in State Set 1 to allow us to have something to nest. Looking at the comments, it is seen that our variable Q is going to be the maximum number of rewards the animal will be allowed. The second topic revisited is Z-pulses. We had a z-pulse in this program already to signal the reward timer. The new z-pulse serves the purpose of terminating certain program functions after our session timer times out or the animal has enough rewards. Without the z-pulse, the animal could get another reward and the response counter could still be counting after the procedure is "terminated." This is because of the three-second-time delay in S3 (needed to allow the screen to update before stopping).

```
\This is an FR-5
\Filename, Tutor06B.mpc
\Date July 7, 2000

\This section is for inputs
^LeftLever = 1

\This section is for outputs
^House = 1
^Reward = 2    \In this code, this is a pellet dispenser.

\DEFINED CONSTANTS
\ A = NUMBER OF RESPONSES
\ B = NUMBER OF REWARDS
\ M = MINUTES
\ X = FIXED RATIO
\ N = SESSION TIMER
\ Q = MAXIMUM REWARD


S.S.1,    \main control logic for "FR"
S1,
  1": SET M = 1; SET X = 5; SET Q = 5 ---> S2

S2,
  #START: ON ^House ---> S3

S3,
  X#R^LeftLever: ON ^Reward; Z1 ---> SX
  #Z2: ---> S1


S.S.2,
S1,
  #START: SHOW 2,RESP,A ---> S2

S2,
  #R^LeftLever: ADD A; SHOW 2,RESP,A ---> SX
  #Z2: ---> S1
```

```
S.S.3,
S1,
  #Z1: ADD B; SHOW 3,REWARD,B ---> S2

S2,
  .05": OFF ^Reward ---> S1


S.S.4,
S1,
  #START: SHOW 1,Sess_n,N ---> S2

S2,
  1": ADD N; SHOW 1,Sess_n, N/60;
      IF N/60 < M [@True, @False]
                \AS LONG AS SESSION TIME < M WE WILL CONTINUE
         @True: IF Q < B [@2True, @2False]
                           \IF ANIMAL HAS ENOUGH REWARDS WE WILL STOP
                   @2True: Z2 --->S3
                   @2False: ---> SX
                 \Z PULSE ADDED WHEN ELAPSED TIME = M WILL GO UP TO
                 \S.S.1 AND WAIT
         @False: Z2 ---> S3

S3,
  3": ---> STOPABORT
```

Tutor06C.mpc

The primary purpose of this program is to see how a compound "IF" statement works. State 2 of state set 4 contains our compound "IF" statement and, in this example, it simplifies the information in Tutor06B.mpc's into four lines (from six).

```
\NOTE: CHANGES IN BOLD ARE CHANGES FROM Tutor06B.MPC
\This is an FR-5
\Filename, Tutor06C.mpc
\Date July 7, 2000

\This section is for inputs
^LeftLever = 1

\This section is for outputs
^House = 1
^Reward = 2    \In this code, this is a pellet dispenser.

\DEFINED VARIABLES
\ A = NUMBER OF RESPONSES
\ B = NUMBER OF REWARDS
\ M = MINUTES
\ X = FIXED RATIO
\ N = SESSION TIMER
\ Q = MAXIMUM REWARD


S.S.1,    \main control logic for "FR"
S1,
  1": SET M = 1; SET X = 5; SET Q = 5 ---> S2

S2,
  #START: ON ^House ---> S3

S3,
  X#R^LeftLever: ON ^Reward; Z1 ---> SX
  #Z2: ---> S1


S.S.2,
S1,
  #START: SHOW 2,RESP,A ---> S2

S2,
  #R^LeftLever: ADD A; SHOW 2,RESP,A ---> SX
  #Z2: ---> S1


S.S.3,
S1,
  #Z1: ADD B; SHOW 3,REWARD,B ---> S2

S2,
  .05": OFF ^Reward ---> S1
```

```
S.S.4,
S1,
  #START: SHOW 1,Sess_n,N ---> S2

S2,
  1": ADD N; SHOW 1,Sess_n, N/60;
      IF (N/60 >= M) OR (B >= Q) [@True, @False]
         @True: Z2---> S3
         @False: ---> SX

S3,
  3": ---> STOPABORT
```

Chapter Eight:
Introduction to Arrays, Part One

The variables used so far have all been simple, non-array variables. Any variable (A to Z) can also be designated as an array with from 2 to 10,001 elements. Although there are certain restrictions when using arrays, over all this is a very powerful means of collecting data and controlling your program. This chapter will deal with a way that you can use arrays to collect data.

The General Concept Behind Arrays:

Once a variable has been assigned, or defined, as an array the elements within that array are identified with subscripts of that variable where the first element is always numbered 0 (zero), and each successive element is consecutively numbered. The individual elements of an array are always accessed through subscripts. In other words, the first piece of data in array "A" would be placed in element 0 and would be referenced by A(0), while the third piece of data would be placed in element 2 and referenced by A(2). If properly defined, this could continue up to the 10,001 piece of data that would be placed in element 10,000 and referenced by A(10000). This, however, would have to be the last piece of data for not only the array, but for the box. It would also have to be the only variable defined because the limit is 10,001 elements per box (i.e., one array of 10,001 or two arrays of 5,000 each, one array of 5,000 plus 5 arrays of 1,000 each, etc.) [7].

DIM Command:

The size of the array must be stated before the first state set. As with all MSN variables, the values of array elements are always equal to 0 until explicitly changed. In a case where you would want your program to fill in your array with data through the course of an experiment (i.e., the array is to be created empty), the DIM (dimensional) command is very useful. Its syntax is:

```
DIM = X

S.S.1,
```

(NOTE: this command doesn't fit into the INPUT: OUTPUT ---> NEXT format, it must always be placed somewhere before S.S.1)

---

[7] An attempt to further explain this concept using this example would probably result in more confusion then actual help. All that needs to be kept in mind when programming is that the maximum number of variables and variable subscripts is 10,001. For example, you could define 21 variables and set up 4 arrays with 2495 elements to satisfy the 10,001 cap or another program with 16 variables, 1 array of 8000, another array of 1500, and 1 array of 485. Also keep in mind, this is only a cap, not a requirement; there is nothing wrong with setting up a program with 3 variables and an array with 50 elements.

Where x = the number of elements you want defined. Remember, arrays start with element zero, so if you wanted an array with 25 elements to fill with data, you write it as:

```
DIM = 24
```

Using An Array To Record IRT's:

An especially useful application of an array is the recording of Inter-Response Time (IRT) data. If your array is dimensioned smaller than the number of IRTs, you will get an error message from WMPC when an attempt is made to use an array element that does not exist.

Sealing An Array:

If defining your array too small results in an error, then it only makes sense that you would want to typically "pad" your array with more elements than you expect to use. But what if, for example, you assign the array to have 500 elements (DIM = 499), but your animal only responds 25 times? The result would be 25 points of data followed by 475 empty elements represented by zeros. Although better than an error message, this is hardly ideal. The secret is to seal your array so that only data recorded is displayed and all superfluous elements are excluded from the data file. This is done with the MedState Notation -987.987 command. In order to use this command, it must be done in conjunction with the "SET" command (e.g., SET X = -987.987). The real code would look like this:

```
S2,
  #R^LeftLever: SET C(I) = T, T=0; ADD I;
                IF B >= Q [@True, @False]
                   @True: ---> S1
                   @False: SET C(I) = -987.987 ---> SX
```

In this example (which will be seen again in the tutorial), every response adds to array C, and then the array is tested. If our statement is true transition takes place to the first statement the collection of IRT's without terminating the procedure (Note: the program will end when the session timer tells it to do so). If the statement is false, however, the seal of our array is moved over one spot. The advantage, of course, being that the array is always "sealed" in case of a true statement or a premature stop but the seal can always be moved.

Tutorial 7A: Using the DIM command

Once again we are going to modify the FR-5 program from Tutor04.mpc. So go ahead and open that file and make the following changes marked in bold, saving it as Tutor07A.mpc and translate/compile it as you have done in the past.

```
\This is an FR-5
\Filename, Tutor07A.mpc
\Date July 7, 2000

\This section is for inputs
^LeftLever = 1

\This section is for outputs
^House = 1
^Reward = 2    \In this code, this is a pellet dispenser.

\DEFINED VARIABLES
\ A = NUMBER OF RESPONSES
\ B = NUMBER OF REWARDS
\ C = DATA ARRAY

DIM C = 49

S.S.1,    \main control logic for "FR"
S1,
  #START: ON ^House ---> S2

S2,
  5#R^LeftLever: ON ^Reward; Z1 ---> SX


S.S.2,    \response counter
S1,
  #START: SHOW 1,RESP,A ---> S2

S2,
  #R^LeftLever: ADD A; SHOW 1,RESP,A ---> SX


S.S.3,    \reward counter
S1,
  #Z1: ADD B; SHOW 2,REWARD,B ---> S2

S2,
  .05": OFF ^Reward ---> S1


S.S.4,    \Time increment in .1 sec intervals.
S1,
  #START: ---> S2

S2,
  0.1": SET T = T + 0.1 ---> SX
```

```
S.S.5,    \Recording IRT'S
S1,
  #START: ---> S2

S2,
  #R^LeftLever: SET C(I) = T, T = 0; ADD I ---> SX


S.S.6,
S1,
  #START: ---> S2

S2,
  1' ---> STOPABORT
```

After opening MED-PC, load and start the program as you normally would. When testing it, take care in not pressing the lever more than 50 times (remember, DIM = 49). When your box times out after one minute, go to file and select print. At the bottom of your print out, you should get something that looks like this:

```
C:
   0:    6.400   0.800   0.400   0.500   0.300
   5:    3.200   0.500   0.300   0.300   0.900
  10:    0.300   0.400   0.600   0.300   0.200
  15:    0.200   0.500   0.200   0.400   0.800
  20:    1.000   1.200   2.300   0.600   1.000
  25:    6.400   0.800   0.400   0.500   0.300
  30:    3.200   0.500   0.300   0.300   0.900
  35:    0.300   0.400   0.600   0.300   0.200
  40:    0.200   0.500   0.200   0.000   0.000
  45:    0.000   0.000   0.000   0.000   0.000
```

This is your data array. The numbers preceding the colon show what the subscript of the first number per row is. Each number that follows is the next subscript Therefore, looking at the 0: row, the value 6.400 = A(0), 0.800 = A(1), 0.400 = A(2), etc.

Tutorial 7B: Sealing the Array

In this tutorial, we are just going to make some changes to the previous tutorial. The changes to be made are noted in bold.

```
\This is an FR-5
\Filename, Tutor07B.mpc
\Date July 7, 2000

\This section is for inputs
^LeftLever = 1

\This section is for outputs
^House = 1
^Reward = 2    \In this code, this is a pellet dispenser.

\DEFINED VARIABLES
\ A = NUMBER OF RESPONSES
\ B = NUMBER OF REWARDS
\ C = DATA ARRAY
\ M = MAX TIME IN MINUTES
\ N = SESSION TIMER
\ Q = MAX REWARD

DIM C = 999

S.S.1,    \main control logic for "FR"
S1,
  #START: ON ^House; SET Q = 5; SET M = 1 ---> S2

S2,
  5#R^LeftLever: ON ^Reward; Z1 ---> SX
  #Z2: ---> S1


S.S.2,    \response counter
S1,
  #START: SHOW 2,RESP,A --- > S2

S2,
  #R^LeftLever: ADD A; SHOW 2,RESP,A ---> SX
  #Z2: ---> S1


S.S.3,    \reward counter
S1,
  #Z1: ADD B; SHOW 3,REWARD,B ---> S2

S2,
  .05": OFF ^Reward ---> S1


S.S.4,    \Time increment in .1 sec intervals.
S1,
  #START: ---> S2

S2,
  0.1": SET T = T + 0.1 ---> SX
```

```
S.S.5,    \Recording IRT'S
S1,
  #START: ---> S2

S2,
#R^LeftLever: SET C(I) = T, T = 0; ADD I;
              SET C(I) = -987.987 ---> SX
#Z2: ---> S1


S.S.6,
S1,
  #START: SHOW 1,Sess_n,N ---> S2

S2,
  1": ADD N; SHOW 1,Sess_n,N/60;
      IF N/60 < M [@True, @False]
         @True: IF Q < B [@2True, @2False]
                   @2True: Z2---> S3
                   @2False: ---> SX
         @False: Z2 ---> S3

S3,
  3": ---> STOPABORT
```

Go ahead and save this program as Tutor7B.mpc, translate/compile it, and go to MED-PC and load/run it. This program will now stop in one of two ways, either because the animal has enough rewards (defined by Q) or the program has run its course (set as one minute). Although we have set our array for a much larger number than we would ever need (1000 elements) it does not matter, the array will seal itself no matter how it stops. When the program gets done running, make a print out. Unlike our last program that had zeros in the array where there were no responses, this printout only shows the data collected. An example of the data from an IRT = 42 is shown below:

```
C:
   0:     3.700    0.300    0.200    0.300    0.500
   5:     0.800    0.200    0.100    0.700    0.100
  10:     0.200    0.200    0.100    0.100    0.100
  15:     0.100    0.100    0.100    0.100    0.100
  20:     8.900    0.500    0.600    0.600    0.500
  25:     0.500    0.800    0.500    0.500    0.800
  30:     3.700    1.300    1.100    4.500    0.800
  35:     0.000   18.100    0.500    0.500    1.400
  40:     0.700    0.900
```

As you can tell, this was an example of the programming timing out as opposed to getting the maximum numbers of rewards. Notice how, unlike the print out from the Tutor07A.mpc, this printout does not have all of the excessive zeros due to the insertion of the -987.987 command.

Chapter Nine:
Array Commands As Outputs
(An introduction to the LIST, RANDI, AND RANDD commands)

The previous chapter dealt with a way to transform a variable into an array just by assigning it a dimensional value. This was a nice way to collect and sort data. Arrays can be used for more than just data collection; they can also be used as control variables in a program. This chapter will deal with how to set up and use arrays in outputs.

LIST (as a definer of arrays):

Unlike DIM, which only allows you to set up the shell of an array that must be filled in (or sealed), LIST allows you to set up an array with assigned values. LIST is best used in conjunction with an output function (this will be demonstrated a bit later). When used to define, the syntax of LIST is:

```
LIST X = V1, V2, V3,…
```

Where X is any available variable and V1, V2, and V3 are all values assigned to the new array X.

LIST (as an output):

The second use of the LIST command is found in the output section of statements. This must be used in conjunction with LIST as a definer. The basic idea behind these two commands is that LIST first defines the array at the beginning of a program. Later in the program when you want to draw from this array, the LIST as an output will draw each number, one at a time and sequentially until the program is done or the numbers have all been used. If the latter occurs, LIST simply starts again at the beginning of the list. The following would successively display the numbers 1, 2, and 3 on the screen, and demonstrates the two uses of LIST:

```
LIST G = 1,2,3
S.S.1,
S1,
  1": LIST F = G(H); SHOW 1,FVAL,F ---> SX
```

RANDI:

RANDI is similar to LIST (as an output) and is used in to automatically select data from an array set up with LIST (as a definer). The difference between LIST and RANDI is that while LIST pulls its values from the array sequentially, RANDI pulls them randomly with replacement. The following example shows how the program above could use the RANDI command:

```
LIST G = 1,2,3
S.S.1,
S1,
  1": RANDI F = G; SHOW 1,FVAL,F ---> SX
```

Note that a subscript variable is not specified for the array variable, as was the case with the LIST command. The subscript is selected randomly as a function of RANDI. Also, unlike the LIST program that would present the data 1, 2, 3, 1, 2, 3,…, this program might cause the numbers 2, 2, 1, 3, 2, 1, 3 to be successively displayed on the screen (so the average, if allowed to run over time would be 1 = 2 = 3).

RANDD:

RANDD is closely related to RANDI with the difference lying in that RANDD randomly selects from an array, but without replacement. Substituting RANDD in the examples of code used above might cause the numbers 1, 3, 2, 2, 1, 3, 2, 3, 1 to be successively displayed on the screen (the point being that any one number cannot be reused until the other two numbers have been selected.

Tutorial 8: Using the List (As a definer) And RANDD To Set Up a VI Schedule

We are going to add/change a few lines of code from the Tutor07B.mpc. As done in the past, the changes are shown below in bold. Make the changes, save as Tutor08.mpc, translate/compile, and then go to MED-PC for Windows and test the program.

```
\This is a VR-10
\Filename, Tutor08.mpc
\Date July 7, 2000

\This section is for inputs
^LeftLever = 1

\This section is for outputs
^House = 1
^Reward = 2    \In this code, this is a pellet dispenser.

\DEFINED VARIABLES
\ A = NUMBER OF RESPONSES
\ B = NUMBER OF REWARDS
\ C = DATA ARRAY
\ D = OUTPUT ARRAY
\ M = MAX TIME IN MINUTES
\ N = SESSION TIMER
\ Q = MAXIMUM REWARD

DIM C = 999

LIST D = 1, 5, 10, 15, 19

S.S.1,    \main control logic for "VR"
S1,
  #START: ON ^House; SET Q = 10; SET M = 1 ---> S2

S2,
  1": RANDD X = D; SHOW 2,VI =,X ---> S3

S3,
  X#R^LeftLever: ON ^Reward; Z1 ---> S2
  #Z2: ---> S1


S.S.2,    \response counter
S1,
  #START: SHOW 3,RESP,A ---> S2

S2,
  #R^LeftLever: ADD A; SHOW 3,RESP,A ---> SX
  #Z2: ---> S1
```

```
S.S.3,    \reward counter
S1,
  #Z1: ADD B; SHOW 4,REWARD,B ---> S2

S2,
  .05": OFF ^Reward ---> S1


S.S.4,    \Time increment in .1 sec intervals.
S1,
  #START: ---> S2

S2,
  0.1": SET T = T +0.1 ---> SX


S.S.5,    \Recording IRT'S
S1,
  #START: ---> S2

S2,
  #R^LeftLever: SET C(I) = T, T = 0; ADD I;
                SET C(I) = -987.987 ---> SX
  #Z2: ---> S1


S.S.6,
S1,
  #START: SHOW 1,Sess_n,N ---> S2

S2,
  1": ADD N; SHOW 1,Sess_n,N/60;
      IF N/60 < M [@True, @False]
         @True: IF Q < B [@2True, @2False]
                   @2True: Z2 ---> S3
                   @2False: ---> SX
         @False: Z2 ---> S3

S3,
  3": ---> STOPABORT
```

Notice as you run this program how the value of VI is shown on the runtime screen. As long as you generate at least five responses you will see that VI will equal 1, 5, 10, 15, 19 (not in that order) before repeating any of those number. This is because of the RANDD command. If you would like to test it for yourself, change RANDD to RANDI to make the selection random with replacement or to LIST to get the numbers to come out sequentially.

Congratulations, you have now mastered all the building blocks necessary to write any program you could imagine. The next chapter will cover some obscure commands that you may or may not find useful in your programming. If you are interested in getting more in depth in any of the commands presented here, flip to Appendix A for a list of all commands and their syntax. Good luck in your MED-PC programming endeavors.

Chapter Ten:
You Have Collected The Data, Now What?
(An introduction to Print and Disk Commands)

Up to this point, we have seen how to assign variables, create and fill arrays, and print this data. Having never used all of our variables, we have had zeros next to those unassigned. Over the course of an experiment, however, this can result in cluttered data files and an exorbitant amount of numbers to slug through to get to the data needed. With WMPC you can establish which data are to be printed and/or saved. As you will soon see, there are times when the printing (PRINT) and data saving (DISK) commands overlap. When this occurs, only the syntax of the PRINT command will be shown, but it will be explained that DISK can be used in place of PRINT.

As you go through this chapter, all of these commands, unless explicitly stated, are written as stand alone statements and must precede the first state set (Like the DIM command from Chapter Eight).

Setting the Orientation of Printouts (PRINTORIENTATION)

This command is used to override system defaults with respect to whether a given printout occurs in landscape (sideways) or portrait (standard) orientation.

The syntax is:

```
PRINTORIENTATION = direction
```

Where direction is "landscape" or "portrait."

Setting the # of Columns on Printouts (PRINTCOLUMNS) [on Data files (DISKCOLUMNS)]:

PRINTCOLUMNS controls the number of columns in which the contents of arrays are printed. The use of this command will override any defaults set within the WMPC menu system (which is five columns). This command functions in combination with PRINTORIENTATION, PRINTPOINTS, and PRINTFORMAT. If the total line space available is exceeded, the column function may be automatically truncated. The syntax is:

```
PRINTCOLUMNS = X
```

Where "X" is the number of columns.

The DISKCOLUMNS command will do the same thing but to the data file. Its syntax is identical.

Controlling Font Size on Printouts (PRINTPOINTS):

PRINTPOINTS controls the size of the font used to print data from the box in which this command is issued. The use of this command will override any defaults set within the WMPC menu system. The syntax is:

```
PRINTPOINTS = X
```

Where X is the number of points (12 is the default).

Controlling the Printouts/Data Files (PRINTFORMAT)/ (DISKFORMAT):

By default, WMPC automatically sets aside 12 spaces for each number to be printed. It breaks down the 12 spaces into 8 reserved for the integer part of the number (to the left of the decimal), 1 for the decimal and 3 spaces for numbers right of the decimal. An example of a number printed in 12.3 format (the meaning of 12.3 will be detailed below) is, "12345678.123".

In many instances, it is useful to print data in other formats, particularly when trying to increase the amount of data printed per page. Placing a PRINTFORMAT statement before the first state set of the procedure you can control the printed format of numbers. The syntax of PRINTFORMAT is:

```
PRINTFORMAT = P1.P2
```

Where P1is the number indicates the total number of spaces to be occupied by the number including the decimal point and P2 is the number indicating the number of spaces to be set aside for the decimal portion of the number.

PRINTFORMAT Examples:

```
PRINTFORMAT = 5.1    \Print in five space, with 3 to left of decimal
                     \1 to right as in 123.1

PRINTFORMAT = 7.2    \e.g., 1234.12

PRINTFORMAT = 6.0    \e.g., 123456
```

The use of a PRINTFORMAT statement has no effect upon the internal representation of numbers. If multiple PRINTFORMAT statements are used in the same .MPC procedure, then only the last one is implemented.

If the digits to the left of the decimal point exceeds the total number of spaces set aside by the PRINTFORMAT statement, then the general formatting rules are temporarily set aside and the number is printed in as many spaces as are needed to represent the integer portion of the number. This may result in the printed line "spilling" onto the next line on the page. If the decimal portion of a number exceeds the space allocated, the number printed is rounded to the nearest value.

Remember, to save the data in the same format, just replace the word PRINT with DISK and follow all of the same rules.

Controlling the Selection of Variables or Arrays on Printouts/Data Files (PRINTVARS) (DISKVARS):

It is often desirable to print only a subset of the variables and arrays in a procedure. This is particularly true when many of the variables are used internally by the procedure and do not contain data. Additionally, when collecting hundreds or thousands of data points per session, it would be convenient to be able to print a few key indices to the printer after every session, and yet be able to save the detailed counters to disk file for later analysis.

The above objectives may be accomplished by using the PRINTVARS command. This command may be used to declare a list of variables that will be printed whenever a PRINT command is issued. The PRINTVARS command affects printing irrespective of whether the command to print was issued from within a state table or by a keyboard command. The PRINTVARS command in no way affects the variables that will be written to disk (but a parallel command, DISKVARS, is provided).

As seen in previous tutorials, by default all variables and arrays (A-Z) are printed. To print selected variables, place a PRINTVARS directive before the first state set of the procedure. PRINTVARS must come before the first state set and its syntax is:

```
PRINTVARS = P1, P2...P26
```

Where P1...P26 are the variables or arrays A through Z that you want printed. Real Code may look like this:

```
PRINTVARS = A, B, C, D, F, G, Z
```

Condensed vs. Full Headers (PRINTOPTIONS):

PRINTOPTIONS provides control over the appearance of the headers that appear at the beginning of printouts as well as when to print your data. The headers include information, such as the time the experiment was loaded and the name of the program used to control the experiment. There are two options for the appearance of headers: FULLHEADERS vs. CONDENSEDHEADERS. For when to print your data, the options are FORMFEEDS or NOFORMFEEDS. If FORMFEEDS is selected, the printout will occur when data is queued to be printed (i.e., when a box is done running). If NOFORMFEEDS is selected, WMPC will print only when a page of data is in the queue. If PRINTOPTIONS is not explicitly specified, the default printout is to print a condensed header and no form feed. When specified, commas separate multiple options, and any option not specified will stay at its default value. The syntax is:

```
PRINTOPTIONS = P1, P2
```

Where P1 = FULLHEADERS or CONDENSEDHEADERS and P2 = FORMFEED OR NOFORMFEED.

Printing Data (PRINT):

PRINT is the only command in this section that is not placed before State Set 1. It is an output command that may be used to generate printouts from within the code. Just like with printing from the menu bar, unless you specify differently (using the aforementioned commands), PRINT will print everything.

All printing is done through the Windows Print Manager. In the event that the printer is offline or out of paper or there is some other problem, Windows will present a dialog box indicating the nature of the problem. It is generally best to correct the problem and the select "RETRY". Data will not generally be lost under such circumstances.

Since it is an output command, the syntax of PRINT is:

```
INPUT: PRINT ---> NEXT
```

And real code may look like this:

```
S2,
  30': PRINT ---> STOPABORTFLUSH
```

Tutorial 9: Bringing it all together

For this tutorial, open up tutor08.mpc and make the following changes noted in bold and save it as tutor09.mpc:

```
\ This is a VR-10
\ Filename, Tutor09.mpc
\ Date July 7, 2000

\This section is for inputs
^LeftLever = 1

\This section is for outputs
^House = 1
^Reward = 2    \In this code, this is a pellet dispenser.

\DEFINED VARIABLES
\ A = NUMBER OF RESPONSES
\ B = NUMBER OF REWARDS
\ C = DATA ARRAY
\ D = OUTPUT ARRAY
\ M = MAX TIME IN MINUTES
\ N = SESSION TIMER
\ Q = MAXIMUM REWARD

DIM C = 999

LIST D = 1, 5, 10, 15, 19

PRINTORIENTATION = LANDSCAPE
PRINT COLUMNS = 4
PRINT OPTIONS = FULLHEADERS, FORMFEEDS
PRINT VARS = A, B, C


S.S.1,    \main control logic for "VR"
S1,
  #START: ON ^House; SET Q = 10; SET M= 1 ---> S2

S2,
  1": RANDD X = D; SHOW 2,VI =,X ---> S3

S3,
  X#R^LeftLever: ON ^Reward; Z1 ---> S2
  #Z2: ---> S1


S.S.2,    \response counter
S1,
  #START: SHOW 3,RESP,A ---> S2

S2,
  #R^LeftLever: ADD A; SHOW 3,RESP,A ---> SX
  #Z2: ---> S1
```

```
S.S.3,    \reward counter
S1,
  #Z1: ADD B; SHOW 4,REWARD,B ---> S2

S2,
  .05":OFF ^Reward ---> S1


S.S.4,    \Time increment in .1 sec intervals.
S1,
  #START: ---> S2

S2,
  0.1": SET T = T + 0.1 ---> SX


S.S.5,    \Recording IRT'S
S1,
  #START: ---> S2

S2,
  #R^LeftLever: SET C(I) = T, T = 0; ADD I;
                SET C(I) = -987.987 ---> SX
  #Z2: ---> S1


S.S.6,
S1,
  #START: SHOW 1,Sess_n,N ---> S2

S2,
  1": ADD N; SHOW 1,Sess_n, N/60;
      IF N/60 < M [@True, @False]
         @True: IF Q < = B [@2True, @2False]
                    @2True: Z2 ---> S3
                    @2False: ---> SX
         @False: Z2 ---> S3

S3,
  5": PRINT ---> STOPABORTFLUSH
```

Translate and compile the program as usual, open it in WMPC, and run. After one minute you should get a print out of the data you specified in a landscape format. The data file, on the other hand, will contain all variables and arrays in the default format. This is the first program we have written with a STOPABORTFLUSH command in it. We did this so a data file would be made and you could compare your printout with the data file. The data file was saved under MED-PC's automatic naming system (unless you changed that yourself). Consult your MED-PC User's Manual for an explanation of how and where MED-PC saves files, if necessary.

Congratulations, you now have all the building blocks necessary to program in MedState Notation!

Chapter Eleven:
So How Does This Work
(The MED-PC: Theory Of Operation)

This chapter is written for the experienced MED-PC user or for one who has read the rest of this manual and is interested in some of the background information. A thorough understanding of this chapter content, although not required to begin using the system, is invaluable when trying to determine why a particular program does not perform as anticipated.

Time-Based Interrupts:

Many of the features of the current version of MED-PC are possible because it is an interrupt-based system. Most of the time, MED-PC is occupied by performing non-critical, non-experimental operations such as responding to user keystrokes, displaying the output of SHOW commands, writing to disk and the printer, etc. Periodically, these activities are "interrupted" and attention is shifted to active boxes. These interrupts occur immediately; regardless of what actions the computer is performing. Even in the middle of writing to disk, the occurrence of an interrupt immediately shifts attention to the experimental boxes. The frequency with which interrupts occur (and boxes are serviced) is equal to the system resolution value declared during system installation with "Hardware Configuration." For example, on a system installed with 10 ms resolution, the boxes are serviced every 10 ms. In the discussions that follow, it will be assumed that a system with 10 ms resolution is applicable. These timed-based interrupts are generated by crystal-controlled interrupt hardware on the interface card that plugs into the chassis of the PC.

Noting And Reacting To Inputs:

As soon as an interrupt occurs, any ongoing activity is suspended and processing of all active boxes commences. Before any individual boxes are processed, the status of all inputs is read and recorded. Thus, if an #R1 has occurred in Box 1 and an #R1 has occurred in Box 3, these events will be noted and made available to the respective boxes when the boxes are serviced (soon to commence). Any keyboard #R's presented from the keyboard since the initiation of the last processing sweep will be merged with any that were read from the input cards. For example, if a keyboard #R1 was recently generated for Box 3 and a hardware #R2 for Box 3 was also recorded, both #R1 and #R2 will be presented to Box 3 during the present sweep. Only one instance of a given response for a single Box may occur during a single sweep. Thus, if #R1 was issued from both the keyboard and was present on the interface for the same Box since the last interrupt, only one instance of the #R1 will be presented to the Box. A statement of the form "2#R1--->S2" would require a response on another sweep in order for a transition to S2 to occur. Similarly, if the subject responded twice on the same input between the occurrences of two interrupts, only one response would be counted.

Before becoming alarmed that a response may be missed, remember that:

- For years 50ms was the finest resolution provided by any programming system.
- Responses are latched in the hardware buffer until read (contact does not have to be coincident with the interrupt).
- Most users install their systems with a resolution of 10 milliseconds...far faster than subjects can respond.
- The minimum response time is not dependent on resolution, but rather the response frequency of the hardware. MED Associates SmartCtrl Cards use a response frequency of 100 Hz whereas Standard and SuperPort modules range from 7 Hz to 400 Hz.
- As a fine point, two responses occurring less than 10 ms apart will actually be resolved if one occurs before a given interrupt (processing sweep) and the other occurs after the interrupt.

Further discussion of theoretical vs. practical timing resolutions is provided at the end of this section.

Order Of Processing Of Boxes:

After preliminary events have occurred (i.e., recording of inputs) individual boxes are serviced in sequential order, beginning with the first active (loaded) Box. Please note that inactive (unloaded) boxes receive no processing and lower-numbered boxes are processed before higher-numbered boxes. In other words, if you have four boxes, but only load boxes 1, 4, and 3. Box 1 will be processed first, Box 2 will be ignored, Box 3 will then be processed and finally processing will occur on Box 4.

Order Of Processing Of Events Within A Box:

Once processing of a Box's state sets begins, the "first" state set of the procedure is serviced. Next, the remaining state sets are processed in the order in which they appear in the .MPC procedure file or "state table," not by the assigned numerical label. Processing then proceeds to the next active Box. For example in the following code, S.S.2 will be processed prior to S.S.1:

```
S.S.2,
S1,
  #R1: ADD A ---> SX


S.S.1,
S1,
  #R2: ADD B ---> SX
```

Processing of States:

The State within each state set that gets processed depends on the "current" State of any given state set. When loaded, the first State listed will always be the "current" State of any procedure until the input requirements of that State are met and a transition occurs. Again, this is independent of the numbering of the States. In the state set that follows, S10 will be the current state when the procedure is loaded and will remain "current" until #R1 occurs:

```
S.S.3,
S10,
  #R1 ---> S5

S5,
  1": ADD A ---> S10
```

Processing of Statements within a State:

As indicated above, processing of an .MPC procedure file starts with the first state set listed as being the current State. Processing of statements within a State also proceeds from the top down with the caveat that those statements associated with external inputs (i.e. #R, #K, ", ', #T, and #START) are processed before those statements associated with internal inputs (i.e., Z-pulses). Within each current state, processing continues until a statement is encountered in which the stated input condition has been met or until the last statement has been reached.

In the following example, S1 of S.S.5 begins by ignoring the Z-pulse in line 3. Assuming an #R1 has occurred prior to the initiation of the current sweep, the internal variable that tracks the total number of responses on R1 in S.S.5, S1 is incremented. The current state remains S1 since two #R1s are required to cause a transition to S2. Additionally, processing of the state proceeds downward to line 5 because the input requirement was not satisfied and no transition (either to SX, the same state or to a different state) has occurred. If an #R2 occurs, the #R2 input count will be incremented, but, since three #R2s are required, processing continues within S1. Line 8 is then processed, and if Z1 is issued (i.e., if 1 second has elapsed), a second "sweep" of the procedure begins in which only #Z-pulse inputs are processed. Now, processing of S.S.5, S1 issues a transition to S3 (not shown). If S.S.5, S1 is re-entered all counters are reset to zero.

Example:

```
S.S.5,              / Line 1
S1,                 /      2
  #Z1 ---> S3       /      3
  2#R1 ---> S2      /      4
  3#R2 ---> S4      /      5

S.S.6,              /      6
S1,                 /      7
  1": Z1 ---> SX    /      8
```

A Review of the General Principles:

When reading this section, there is something very important to keep in mind. Although it may take up to a few minutes for us to read this review, all of this is occurring in the FIRST MILLISECOND of each 10 ms interrupt.

1. External inputs are processed first.

    A. External inputs refer to:

i.	#R	(Used to input a response via interface modules)
ii.	#K	(Used to input a "signal" from another box)
iii.	"	(Used with a numerical value to time in seconds, e.g., 5")
iv.	'	(Used with a numerical value to time in minutes, e.g., 2')
v.	#T	(Used with a variable to define a timed input)
vi.	#START	(A user issued command)

2. Z-pulses are ignored during the processing of "external" inputs.

3. Processing is done in a top-down fashion.

    A. The first states set listed is processed first, followed by the subsequent state sets in the order LISTED; state set numbers (1 to 32) do not determine processing order.

    B. Within a state set, the "current" State is processed.

        i. The current State at the beginning of program execution is that which is physically first in the state set.
        ii. The current State is changed as the result of transitions that occurs when a statement's input requirements are satisfied. A state change resulting from an external input becomes the "current" state for the processing of Z pulses.

    C. Statements within a state set are processed in a top-down fashion, with the proviso, that Z-pulses are ignored during the processing of external inputs.

4. Processing of a State stops as soon as a statement's input requirements are satisfied.

    A. As inputs (K's, R's, Start) are encountered, the counters associated with them are incremented as appropriate. As soon as the input side of a statement is satisfied, any subsequent counted inputs do not have their counters incremented.

        i. This is true irrespective of whether the satisfied statement is performing a transition to SX, the same state or a different state.
        ii. Although there are no counters associated with time-based inputs, the effect of a time-based transition is analogous to that of the "counted" inputs in that satisfaction of a time-based input also halts further processing of the present state.

5. All Z-pulses issued in the output section of statements during the processing of external inputs are noted and held for use as input during the Z-pulse processing phase.

    A. Only one instance of a given Z-pulse is recorded during processing of external inputs, but more than one different Z-pulse may be counted. If, for example, a time-based statement issues two #Z1's in its output section, the effect of doing so does not differ from issuing a single #Z1. Similarly, issuing #Z1 from multiple States is equivalent to issuing a single #Z1.

6. After the completion of processing of external inputs, one or more passes is made through the state table, provided that at least one #Z-pulse was issued during the external-processing phase.

7. The current state of a given state set during Z-pulse processing is that state it was left in at the conclusion of external-input processing. Thus, if the current state of a state set changes from State 1 to State 2 during external-processing, #Z-pulses will be processed in State 2 during Z-pulse processing.

8. During Z-pulse processing, only Z-pulses serve as input, all other inputs are ignored.

9. Processing priority rules for stacked Z-pulses are analogous to those for external inputs.

10. Any new Z-pulses issued during Z-pulse processing are held until the bottom of the state table is reached, at which time a new Z-pulse processing pass will be initiated.

    A. During any given Z-pulse processing pass, only Z-pulses generated during the immediately preceding pass will be presented during the present pass.

    B. Up to 9 consecutive Z-pulse processing passes may occur. If a tenth pass is required to resolve the actions of the state table, processing of the state table will be terminated and the on screen error indicator will be activated, with a corresponding entry made in the Journal. This is done to avoid the occurrence of "endless loops" which could indefinitely delay processing of events in other boxes. The box will, however, be processed at the beginning of the next processing sweep.

    C. Within a state set, a new state entered during a given Z processing pass becomes the current state when (and if) a subsequent Z processing pass occurs. Thus, if transition from S1 to S2 occurs as the result of a Z-pulse, and another processing pass is occasioned by the generation of Z-pulses during the earlier pass; S2 will be the current state in which further Z-pulses may be detected. The final states that result from transitions during Z-pulse processing will remain; of course, the "current" state when external inputs are processed upon occurrence of the next interrupt.

EXAMPLES:

The following code results in a SHOW display, as soon as K1 is issued, of AVAL with a value of "1" in position 1 and CVAL incrementing in position 3. BVAL is never displayed and subsequent occurrences of K1 are not reflected in AVAL since S.S.1 remains in S3 after processing is complete.

EXAMPLE A:

This illustrates that processing of Z-pulses continues, and progressions through more than one State may occur during Z-pulse processing.

```
S.S.1,
S1,
  #Z1: Z2 ---> S2
  #K1: ADD A; SHOW 1,AVAL,A ---> SX

S2,
  #Z2 ---> S3    \ #Z2 detected in same clock tick in
                 \ which it is issued.
  0.1": ADD B; SHOW 2,BVAL,B ---> SX
                 \ Never executed
                 \ #Z2 always occurs immediately

S3,
  0.1": ADD C; SHOW 3,CVAL,C ---> SX


S.S.2,
S1,
  #K1: Z1 ---> SX
```

EXAMPLE B:

The following code changes the second statement in State Set 1 so that transition occurs to S1 (replacing SX). The result, however, is exactly the same as in Example A.

```
S.S.1,
S1,
  #Z1: Z2 ---> S2
  #K1: ADD A; SHOW 1,AVAL,A ---> S1

S2,
  #Z2 ---> S3
  0.1": ADD B; SHOW 2,BVAL,B ---> SX

S3,
  0.1": ADD C; SHOW 3,CVAL,C ---> SX


S.S.2,
S1,
  #K1: Z1 ---> SX
```

EXAMPLE C:

In this code, issuing K1 places S.S.1, S1 into S4. Hence, when the Z1 is issued in S.S.2, S.S.1 S1 is no longer active – S4 becomes the active state. As a result, B and C are not displayed when K1 is issued.

```
S.S.1,
S1,
  #Z1: Z2 ---> S2
  #K1: ADD A; SHOW 1,AVAL,A ---> S4

S2,
  #Z2 ---> S3
  0.1": ADD B; SHOW 2,BVAL,B ---> SX

S3,
  0.1": ADD C; SHOW 3,CVAL,C ---> SX

S4,
  1": ---> SX


S.S.2,
S1,
  #K1: Z1---> SX
```

EXAMPLE D:

In the following code, #K1 causes a transition to S5 in S.S.1. In S.S.2, it generates #Z1. During the Z-pulse-processing phase, S.S.1 is in S5 so the Z1 required for transition is received and "INS5: 1" is displayed on the screen, upon issuance of the first #K1 from the keyboard. A second #K1 will display a 2, a third, 3, etc.

```
S.S.1,
S1,
  #Z1: Z2 ---> S2
  #K1: ADD A; SHOW 1,AVAL,A ---> S5

S2,
  #Z2 ---> S3
  0.1": ADD B; SHOW 2,BVAL,B ---> SX

S3,
  0.1": ADD C; SHOW 3,CVAL,C ---> SX

S5,
  #Z1: ADD D; SHOW 4,INS5,D ---> SX


S.S.2,
S1,
  #K1: Z1 ---> SX
```

Additional Commentary on Time Based Inputs:

Time-based inputs (", ', #T) are subject to the same rules and considerations with respect to order of processing and the consequences of stacking as is true of the other external inputs (#K, #R, #START) but a few points may not be readily apparent.

1. Timers continue to time even when stacked with other external inputs but cannot cause a transition (to SX, to the same state, or to another state) unless they are processed prior to other inputs for which an input actually occurred. Once a timer has elapsed, it will continue to be eligible to cause a transition, provided that the current state has not changed, until it is the first statement capable of causing a transition.

2. It is never a good idea to stack timers with durations equal to the system resolution above other external inputs, for the other inputs will never receive processing because the timer will always cause a transition.

3. Timers with durations equal to the system resolution may be stacked beneath other inputs. Note, intervals specified for less than the resolution interval (the interrupt sweep interval) will be processed as though they were equal to the resolution interval.

4. In the following situation, imagine a system resolution of 10 milliseconds and that an #R1 occurs and the 10" time duration times out on the same interrupt sweep. (Within the 10 millisecond window between interrupts). In this unlikely occurrence, A will be added and transition to S2 will occur during the subsequent interrupt, or 10.01" after entry into the state, provided that another #R1 does not occur within 10 milliseconds of the first response which is probably physically impossible. Stated differently, transition to S2 will not occur until a clock tick occurs in which no #R1 has occurred and the elapsed time is >= 10" since entry into S1.

```
S.S.1,
S1,
  #R1: ADD A ---> SX
  10" ---> S2
```

Accuracy of the MED-PC System:

The MED Associates Inc. millisecond timer, which generates the interrupt signal, features a precise microsecond crystal with an accuracy of 0.001%. Keep in mind that all PC's are sequential processors and therefore can only do one thing at a time, although by virtue of their speed they appear to do multiple tasks simultaneously. The actual processing speed of any system depends upon the number and complexity of the procedures run, but the resolution of timed events is determined by the interrupt interval (resolution) set during the running of MPC2INST. Some users may wish to think of this as one clock tick. Theoretically, it is possible to err in timing by one clock tick -- as is

the case with all timing systems. In practical applications however this becomes a concern only when several conditions are met (i.e., the processing time for all boxes is both inconsistent and at times approaches the resolution value, and time durations have been set equal to the resolution value). The MED-PC system provides a speed warning system that monitors the average processing or sweep time. This does not inhibit the performance of the system in any way, but alerts the user to possible procedure shortcomings before they become a problem. Remember, this is an interrupt-based system. Interrupts are extremely precise and all external inputs (both responses and timed events) are serviced prior to further processing.

At the risk of making MED-PC appear less accurate than it really is, the following illustration demonstrates a "worst case" situation for MED-PC. Consider a computer that just barely keeps up with the 10 millisecond resolution set during installation and 12 boxes are running the same procedure. This procedure is designed to turn an output alternately turned on and off every 10 ms. The results are that Box 1 performs exactly as expected, but the timing in Box 12 is somewhat less precise. This is because Box 1 is always serviced immediately after initiation of a sweep. In contrast, the processing of Box 12 is dependent on the amount of time it takes to process the preceding 11 boxes on each sweep. The potential problems that this could pose are illustrated by a scenario in which a sweep is initiated, and boxes 1 through 11 require 9 ms to process. Box 12's output would be toggled on 9 ms after initiation of the sweep and the next sweep would occur 1 ms later. If on the second sweep, boxes 1 through 11 required very little time to process, such that Box 12 is serviced 1 ms after initiation of the sweep, its output would be turned off 2 ms after being turned on (rather than the 10 ms separation specified by the procedure). NOTE: This is not a cumulative source of errors and would never be any greater than the resolution value. An extremely important point to bear in mind is that this discussion reflects a very unlikely situation in which the system oscillates from moment-to-moment between the boxes requiring substantial time to process and the boxes requiring minimal processing time. The actual behavior of a MED-PC system can be expected to be closer to one in which any given box is processed at intervals approximating the nominal resolution value because the demands of the boxes average out, with some boxes active on one sweep and others active on the next. This is especially true when the boxes have timers with minimum durations of at least twice the resolution value. The error, in practice, will also usually be much smaller than +/- the resolution value provided that the average sweep duration (displayed on screen by the "A:" indicator on the status line) is appreciably less than the resolution value.

Appendix A:
MedState Notation Commands

The chapters of this manual are designed to get one comfortable with the programming of MedState Notation and the introduction the most frequently used commands. This Appendix, however, lists all MedState Notation commands and is presented in detail, with syntax, comments, examples and discussion. They have been grouped as follows, Input Section Commands, Output Section Commands, Mathematic Commands including decision functions, Array Functions, Data Handling Commands, and Miscellaneous Commands. Each command is indexed for convenience.

Input Commands

Reacting to responses (#R)
Fixed Time Inputs (" and ')
Variable Time Inputs (#T)
ORing Inputs (!)
K Signals (#K)
Z Pulses

Output Commands

Controlling Outputs
Turning outputs on (ON)
Turning outputs off (OFF)
Locking outputs on or off (LOCKON and LOCKOFF)

Coordinating Events Across State Sets
Z Pulse Generation

Coordinating Events Across Boxes
Inter-box Communication Via K Commands

Performing Computations and Counting
Incrementing Variables (ADD)
Decrementing Variables (SUB)
Incrementing or Decrementing to a Limit Value (LIMIT)
Mathematical Assignment (SET)
Recording Frequency Distributions (BIN)

Decision Functions
Logical Comparisons (IF)
Probability Gates (WITHPI)

Array Functions
Sequentially Selecting Items from an Array (LIST)
Random Selection, With Replacement (RANDI)
Random Selection Without Replacement (RANDD)
Setting All Array Elements to Zero (ZEROARRAY)
Copying Elements of One Array to Another (COPYARRAY)

Displaying, Printing and Saving data
Displaying Data Onscreen (SHOW)
Printing Data (PRINT)

Stopping the Procedure
STOPKILL
STOPABORT
STOPABORTFLUSH

Miscellaneous output commands
DATE and TIME

Commands that Come before the First State Set:
Declaring Arrays
DIM -- Dimensioning Arrays
Declaring an Array with the LIST Command

Declaring Constants
Constants

Controlling the Appearance of Printouts
Printout Appearance Options

Controlling the Appearance of Disk Files
Disk File Appearance Options

Year 2000 Compatibility
The Y2KCOMPATIBILITY directive

Input Section Commands

#START

#START: is used to hold a state set in a given state until the "#START:" command is issued via the keyboard by the operator. #START: may appear in any state set and may appear more than once. This command is useful for allowing the operator to load procedures and place subjects in chambers before actually initiating the experimental session as well as allowing the setting of variable values, either from the keyboard or via macros.

Syntax: P1#START:

Where: P1 = number, constant, variable, array element, or special identifier.

Comments: P1, since it is unclear when specifying a count would be useful, it is generally not stated and defaults to 1

Examples and Discussion:

```
#START: ---> S2          \ go to state 2 following #START
#START: ON 1 ---> S2     \ turn on 1 and go to state 2 following #START
5#START: ---> S2         \ wait for 5 #START commands before proceeding
                         \ to state 2
```

Remember, WMPC procedures actually begin to execute as soon as they are loaded. #START: does not initiate the procedure, it is merely a mechanism for holding a state set in a given state until the operator provides keyboard input. Also, #START: and program start dates and times in WMPC printouts and data files are unrelated.

#R

#R is satisfied by "responses" resulting either from keyboard simulation (see Chapter 2 of the WMPC User's Manual), or from satisfying the electrical requirement of an input on the MED ASSOCIATES interface [8]. It has two parameters, P2 that specifies a logical input number, and P1 that specifies the number of responses that must occur to progress to the output section of the statement.

Syntax: P1#RP2

Where: P1 & P2 = number, constant, variable, mathematical expression, array element, or special identifier.

[8] A variety of modular and stand-alone interface cards are available. The most common input is a 28 VDC ground signal or a TTL 5VDC sinking logic signal.

Comments: P1 defaults to 1 if not stated

P2 must be a legal input in the range 1...80 defined in the MPC2INST.DTA file

Examples and Discussion:

```
5#R3: ON 1 ---> SX
```

In the preceding example, Output 1 will be turned on after five responses have occurred on Input 3. If P1 is omitted, as in "#R3: ON 1 ---> SX", P1 defaults to 1 and the first response will turn on Output 1. P1 is reset upon entry to a state. #R is unrelated to the variable "R".

A common misconception of beginning MSN programmers is that an external input may be detected in only one state set at a time. In actuality, a single #R, #K, or #START: may be detected and processed in multiple state sets, without penalty of efficiency or processing speed. In the following example, an occurrence of #R1 would place three Show's on the screen:

```
S.S.1,
S1,
  #R1: ADD A; SHOW 1,FIRST,A ---> SX


S.S.2,
S1,
  #R1: ADD B; SHOW 2,SCND,B ---> SX


S.S.3,
S1,
  #R1: ADD C; SHOW 3,THIRD,C ---> SX
```

#Z (Z pulses as inputs)

Z-pulses are used to communicate between state sets and are generated in the output section of a MSN statement (See the output commands section of this appendix). When placed in the input section of a MSN statement they perform in a manner analogous to responses (#R). #Z is unrelated to the variable "Z."

Syntax: P1#ZP2

Where: P1 & P2 = number, constant, variable, mathematical expression, array element, or special identifier.

Comments: P1 defaults to 1 if not stated

P2 must be in the range 1...32

P1 is reset upon entry to the state.

Example:

```
S.S.1,
S1,
  #Z1: ON 1 ---> S2
```

#K

This command like the Z-pulse may be found in either the input or the output section of a statement. It may be used to communicate with procedures via the keyboard as shown in Chapter 2 of the WMPC User's Manual, and may also be used to allow boxes to communicate with one another. (See the description of K-pulses in the section of this chapter covering output commands). When placed in the input section of a MSN statement they perform in a manner analogous to responses (#R). Indeed, the syntax rules for #K are identical to those for #R. One common use for #K is in yoked experiment using the special identifier "Box" as the P2 parameter. #K is unrelated to the variable "K."

Syntax: P1#KP2

Where: P1 & P2 = number, constant, variable, mathematical expression, array element, or special identifier.

Comments: P1 defaults to 1 if not stated

P2 must be in the range 1...100

Examples and Discussion:

Example A: Yoked Shock
(NOTE: BOX is explained on page 80)

```
S.S.1,
S1,
  #K(BOX – 1): ON ^SHOCK ---> S2

S2,
  2": OFF ^SHOCK ---> S1
```

Example B: Free or Shaping pellet
(NOTE: "!" (Logical OR) is explained on page 71)

```
S.S.2,
S1,
  #START: ---> S2

S2,
  #K100 ! A#R1: ON 1 ---> S3      \ REINFORCE AFTER EVERY "A" RESPONSES
                                  \ OR A FREE REINFORCER IF OPERATOR
                                  \ ISSUES #K100

S3,
  .1": OFF 1; ADD C;
       IF C >= B [@END, @CONTINUE]
          @END ---> STOPABORT     \ SESSION ENDS AFTER B RFS
          @CONT ---> SX
```

Example C:

```
S.S.1,
S1,
  #R: ON ^PELLET ---> S2
  #K1: ---> STOPABORT

S2,
  .05": OFF ^PELLET ---> S1
```

Explicit Time Inputs:

" (Seconds) and ' (Minutes)

Time, specified in terms of seconds or minutes, may be used as an input condition.

Syntax: P1" or P2'

Where: P1 & P2 = number or constant

Comments " = Seconds
' = Minutes

Legal Examples:

```
a) 1": ON 1 ---> SX
b) .5": ON 1 ---> SX
c) 5.2': ON 1 ---> SX
d) .5': ON 1 ---> SX
e) ^Dur = 2

S.S.1,
S1,
  ^Dur": ---> S2
```

Illegal Example:

```
f) A": ON 1 ---> SX
```

As can be seen in the examples above, time may be specified as decimal quantities, unless P1 is a constant. When a fractional minute is specified, (example c above), the decimal portion corresponds to fractional minutes, not seconds. When specifying time values it is most precise to use values that are multiples of the temporal resolution declared during the installation procedure (typically 10 milliseconds). Time values falling between two multiples will be treated as the higher of the multiples. For example, WMPC handles 0.245" as 0.25". Time values are reset upon entry to a state.

A fundamental rule is that only one time expression may occur within a single state. The following is illegal and will produce a WTRANS error message:

```
S.S.1,
S1,
  1":ON1--->S2
  2':OFF 2--->S2
```

Variable Time Inputs:

#T

Time values may also serve as inputs without an explicit declaration. This may be accomplished by using #T proceeded by a variable containing a specified amount of time.

Syntax: P1#T

Where: P1 = a variable, array element, or mathematical expression.

LEGAL EXAMPLES:
Example A:

```
S.S.1,
S1,
  1": ON 1; SET X = 1" ---> S2

S2,
X#T: OFF 1 ---> S1
```

Example B:

```
LIST X = 1", 2", 3"

S.S.1,
S1,
  1": ON 1 ---> S2

S2,
  X(0)#T: OFF 1 ---> S1
```

In Example A, X is set equal to one second and then used in State 2 as the parameter to #T. The effect of the procedure segment is to repeatedly turn output 1 on for 1" and off for 1". Example B manipulates output 1 in a similar fashion, but demonstrates the use of an array element as the parameter. A common misconception is that array variables may be set to time values only through a list declaration. The following examples, in which B(0)=5" and B(1)=10" are equivalent:

```
LIST B = 5", 10"

#START: SET B(0) = 5", B(1) = 10" ---> S2
```

As with explicit time values, only one time command per state may be present.

```
S.S.1,    \ ILLEGAL EXAMPLE
S1,
  X#T ---> SX
  1" ---> SX

S.S.1,    \ ILLEGAL EXAMPLE
S1,
  X#T ---> SX
  Y#T ---> SX
```

Time Inputs Less Than the Resolution Value

The minimum amount of time that an MSN procedure can time is equal to the resolution parameter declared during installation. A system set up with 10 ms resolution can not time events less than .01". On a system with 10 ms resolution, the following code would increment A every 10 ms. If the resolution was 25 ms, then A would increment every 25 ms. Using time inputs less than the resolution value causes no particular stress to WMPC run-time programs -- just be advised that they become equal to the resolution value.

```
S.S.1,
S1,
  0.001": ADD A ---> SX    \ Increments A every 10ms not every 1ms
```

A possibly less obvious situation arises when programs are run without an interface and the PC's internal clock (as opposed to the MED crystal timer) is used for timing; since the PC's timer cannot time in units less than 66 ms, this value becomes the effective resolution. If timing seems to be slow or inaccurate while debugging a procedure without an interface, test the program with an interface.

Internal Representation of Time

Time values in seconds (") or minutes (') are represented internally as the numeric value multiplied by the result of (1000 / the systems resolution value in seconds or minutes). For example, on a system with 10 ms resolution, the variable A in the following expression would be internally set to 100 by MED-PC:

```
#R1: Set A = 1" ---> SX
```

Examining A with the VARS command or in a WMPC printout would show that A=100. A useful trick for displaying time values with SHOW commands is to divide the value by 1" (or 1', depending on the units of the time value) prior to display. For example:

```
LIST B = 1", 2", 3"

S.S.1,
S1,
  #START: RANDI A = B; SHOW 1,TIME,A/1" ---> SX
```

Using Logical OR "!" with Input Commands

It is often desirable to permit several conditions to cause transfer to the same output section. For example, to allow presses on either a left lever or a right lever to produce reinforcement, one could write the following code:

```
S.S.1,
S1,
  #R1: ON 1 ---> S2
  #R2: ON 1 ---> S2

S2,
  0.1": OFF 1 ---> S1
```

A more desirable way to code this, however, is to use a logical OR, indicated by placing an exclamation point "!" between two or more input commands. For example, the following code indicates that either #R1 or #R2 is acceptable:

```
S.S.1,
S1,
  #R1 ! #R2: ON 1 ---> S2

S2,
  0.1": OFF 1 ---> S1
```

OUTPUT SECTION COMMANDS

OVERVIEW

Output section commands fall between the colon and arrow of a statement. Multiple output commands may be separated by semicolons, ";" while multiple parameters for the same command are separated by commas, ",". An example of separating output commands is:

```
S1,
  #R1: ON 1, 5; ADD X ---> SX
```

The output section commands are divided into those responsible for turning outputs on and off (ON, LOCKON, OFF, LOCKOFF) including the PC's speaker (ALERTON, ALERTOFF), the mathematics commands (ADD, SUB, SET, BIN, LIMIT), the decision functions (IF, WITHPI), array functions (LIST, RANDD, RANDI, COPYARRAY, ZEROARRAY, data handling (SHOW, CLEAR), and miscellaneous commands (STOPABORT, STOPKILL, STOPABORTFLUSH).

Turning outputs on and off:

ON

ON is used to turn outputs on. Turning on an already active output has no effect.

Syntax: ON P1

Where: P1 = number, constant, variable, array element, or mathematical expression.

Comments: Comma separation permissible

Examples:

Activate a stimulus light (output 1) and grain feeder (output 2) for 4 seconds:

```
^Feeder = 2

S.S.1,
S1,
  #R1: ON 1, ^Feeder ---> S2

S2,
  4": OFF 1, ^Feeder ---> S1
```

OFF

OFF turns off the specified output. It is the opposite of ON.

Syntax: OFF P1

Where: P1 = number, constant, variable, array element, or mathematical expression.

Comments: Comma separation permissible

Example:

```
S1,
  #R1: OFF 1, 2, ^Feeder, A(K), X ---> S2
```

LOCKON and LOCKOFF

LOCKON and LOCKOFF commands supplement ON and OFF, and like ON and OFF, may be issued from the menu system (See WMPC User's Manual) or from the output section of an MSN statement, but with somewhat different effects. They are more powerful versions of ON and OFF in the sense that an output turned on by ON may be shutoff by either OFF or LOCKOFF, but an output turned on by LOCKON may only be shut off by LOCKOFF. Essentially, until a LOCKOFF is issued, OFF will not deactivate an output activated by LOCKON. In contrast, LOCKOFF will shut off an output, irrespective of whether it was activated by ON or LOCKON.

If an output has been turned on by ON and a LOCKON for the same output is issued, the output is upgraded from ON status to LOCKON status. Outputs activated by LOCKON remain on even after a box is unloaded by STOPKILL or STOPABORT and are not even turned off when the system is shutdown and the CPU is turned off. The only way to shut off an output activated by LOCKON is by executing a LOCKOFF.

LOCKON and LOCKOFF are especially useful in conjunction with an output that must be left on even when boxes wired to it are not running. An example of this requirement arises chamber ventilation fans are controlled by WMPC; subjects still need fresh air even when their box is not running. Another application of LOCKON might be a light attached to the door of a running room. The output that drives the light could be shared by all boxes and LOCKON'd by each box as it loads. By using LOCKON, the light is not shutoff every time a box terminates (because of automatic shutoff outputs activated by ON). When all sessions have finished, the technician could execute a keyboard macro to LOCKOFF the relevant output to extinguish the light. For further discussion of output sharing, refer to the next section, "Overlapping Inputs and Outputs."

Syntax: LOCKON P1 or LOCKOFF P1

Where: P1 = number, constant, variable, array element, or mathematical expression.

Comments: Comma separation permissible

Overlapping Inputs and Outputs

It is an acceptable practice to have a given bit on an input or output card assigned to more than one logical box. For example, all boxes might have output one mapped to output card 780, bit #1. This kind of output sharing is used in one of the beta testing labs, where every box turns on output 1 upon loading. This output is mapped to port 780, bit 1 in all boxes and is connected to a relay that turns on all of the chamber ventilation fans.

It is also okay for a box to attempt to turn on an output it doesn't have. For example, some operant chambers may have lever extension solenoids but some of the others do not. The chambers with solenoids are wired to six outputs, whereas the remaining boxes each have four outputs. Never the less, a single procedure is used to run both types of chambers. Irrespective of which type of chambers is actually being run, outputs five and six are turned on to extend or retract the levers (if present).

Input sharing is also permissible and might be used as a panic button to cause all boxes to shut off simultaneously via a push-button wired to a single shared input. Entering a keyboard response (#R) that is not matched by a hardware input has no effect.

WARNING! Assigning a procedure to a box that does not have a hardware input corresponding to an input that the procedure attempts to read would result in a stream of continuous responses being produced.

Z-pulses

A construct known as a Z-pulse may be used to communicate among state sets. Z-pulses are generated in the output section of statements, but may also function as inputs to other statements (refer back to the Input command section for more details on this use of Z-pulses). Z-pulses may have values falling between 1 and 32. They can be an invaluable means for coordinating the action of multiple state sets.

Syntax: Z P1

Where: P1 = number, constant, variable, array element, or mathematical expression with value in the range 1...32.

Warning: It is the programmer's responsibility to ensure that P1 is in range 1...32. If this range is not observed, particularly if violated with a constant, variable array element, or mathematical expression, no warning message will be generated and unpredictable problems will result when programs are running.

Example and Discussion:

Example A:

The following example demonstrates the use of Z-pulses to coordinate an FR 10 on input 1, an FI 30" on input 2 and reinforcement. When either schedule is satisfied, a Z1 is generated in the relevant output section. For example, when the FR 10 is completed, a Z1 is generated. The Z1 then serves as an input to state 2 or 3 of state set 2 (depending on whether or not 30" have elapsed), driving state set 2 to state 4. Simultaneously, the Z1 also serves as an input in state 2 of state set 3, causing an output channel to turn on and transition to state 3. After 2", a Z2 is generated, which then serves as an input to state 3 of state set one and state 4 of state set 2, driving them both back to state 2.

```
S.S.1,    \ FR 10 on Input 1
S1,
  #START: ---> S2

S2,
  #Z1 ---> S3
  10#R1: Z1 ---> S3

S3,
  #Z2 ---> S2


S.S.2,    \ FI 30" on Input 2
S1,
#START: ---> S2

S2,
  #Z1 ---> S4
  30" ---> S3

S3,
  #Z1 ---> S4
  #R2: Z1---> S4

S4,
  #Z2 ---> S2


S.S.3,    \ Reinforcer State Set
S1,
  #Start: ---> S2

S2,
  #Z1: ON 2 ---> S3

S3,
  2": OFF 2; Z2 ---> S2
```

Z-pulses can be tremendously useful, but they must be used wisely. When a Z-pulse is generated, it does not get processed immediately. Instead, a record of all Z-pulses generated during a pass through the state sets of a procedure are recorded and then a second pass is immediately made through the state sets. If more Z-pulses are generated, then yet another pass through the state sets occurs. Each pass, of course, requires processing time. A situation to avoid is having one Z-pulse lead to the immediate generation of another Z-pulse, then another, etc. Below is an example of poor programming utilizing Z-pulses, which could produce a loop that the runtime system will treat as an error after 10 iterations.

Example B:

```
S.S.1,
S1,
  #START ! #Z3: Z1 ---> S2

S2,
  #Z1: ON 1; Z2 ---> S3

S3,
  #Z2: OFF 1; Z3 ---> S1
```

While it is unlikely that one will ever write a series of statements as aberrant as the set above, it is still important to avoid generating chains of Z-pulses wherever possible. The following example is inefficient, for a #Z1 is used as input in state one of state set two to immediately generate a Z2, which is then used in state set three to produce a reinforcer. Although the following code will not cause a system "lock up," it could result in some system performance falling on a slower computer.

Example C:

```
S.S.1,    \ FR 1
S1,
  #Start: ---> S2

S2,
  #R1: Z1 ---> S3

S3,
  #Z3 ---> S2


S.S.2,    \ Record Data
S1,
  #Z1: ADD A; SHOW 1,Rfs,A; Z2 ---> SX


S.S.3,    \ Deliver Reinforcer
S1,
  #Z2: ON 1 ---> S2

S2,
  2": OFF 1; Z3 ---> S1
```

Z-pulse Depth Checking

It has been possible under previous releases to cause a runtime program to lock-up from a never-ending sequence of Z-pulses. If a very long (yet finite) sequence is generated, program performance may suffer greatly. Indeed, most excessively long #Z-pulse sequences are probably errors, rather than planned actions. Generally speaking do not use Z-pulses to repeat other input statements (#R, #K, or #START). It is more efficient to repeat the input statement in multiple state sets. In those instances where a substance such as a latency counter is activated with #START for the first trial and a Z-pulse in subsequent trials, the input may be OR'd or simply disregard the previous rule.

Example A:

```
S.S.1,
S1,
  #Z1 ! 1": #Z1 ---> SX    \Will cause a WMPC runtime error
```

Example B:

A limit of nine consecutive Z-pulses is now considered acceptable. For example: the following is acceptable:

```
S.S.1,
S1,
  1": Z1 ---> SX


S.S.2,
S1,
  #Z1: Z2 ---> SX


S.S.3,
S1,
  #Z2: Z3 ---> SX
        .
        .
        .
S.S.9,
S1,
  #Z8 ---> SX
```

Adding a tenth Z-pulse would cause an error condition in the present version of WMPC. When the tenth Z-pulse in a chain is generated, the "ERROR" indicator on the runtime screen appears and flashes. Additionally, an entry is made in the journal, and the chain of Z-pulse is terminated; Z-pulse chains longer than nine are no longer tolerated. Once Z-pulse chains longer than two or three are used in a procedure, it is very possible that Z-pulses are being substituted for clear procedure logic (comparable to using lots of GOTOs in a BASIC program).

K-pulses

The K-pulse bears considerable similarity to the Z-pulse in that both may be issued in the output sections of statements and received on the input side. Whereas the Z-pulse is used to communicate between state sets within the same box, the K-pulse is used to communicate between boxes.

An example of a situation in which K-pulses may be useful is yoking procedures in which the behavior of one subject determines the stimuli to which another subject is exposed. In the following code example, the "CONTROL" box is running a procedure that implements a "classic" auto shaping procedure in which a keylight is illuminated following an inter-trial-interval (ITI) of random duration with a mean of 20". Pecking the illuminated key produces immediate 4" access to grain. In the absence of a keypeck, the keylight is extinguished after 8" and grain is delivered. The bird in the yoked box receives the same pattern of stimuli and reinforcers, but that bird has no control over the events. The following pair of procedures, one for the control box and the other for the yoked box, illustrates the use of K-pulses.

(NOTE: “WITHPI” is explained on page 93)

```
\AUTOSHAPING PROCEDURE FOR THE "CONTROL" BOX

^FEEDER=1
^HOUSELIGHT=2
^KEYLIGHT=3

S.S.1,
S1,
  #START: ON ^HOUSELIGHT ---> S2

S2,    \ 20" MEAN ITI.  TELL YOKED BOX WHEN ITI OVER BY SENDING K1
  1": WITHPI = 500 [ON ^KEYLIGHT; K1] ---> S3

S3,    \ TELL YOKED BOX THAT FEEDER IS ON BY SENDING K2
  #R1 ! 8": OFF ^KEYLIGHT; ON ^FEEDER; K2 ---> S4

S4,
  4": OFF ^FEEDER ---> S2

=====================================================

\AUTOSHAPING PROCEDURE FOR THE "YOKED" BOX

^FEEDER=1
^HOUSELIGHT=2
^KEYLIGHT=3

S.S.1,
S1,
  #START: ON ^HOUSELIGHT ---> S2

S2,    \ K1 SENT BY CONTROL BOX WHEN KEYLIGHT TURNED ON
  #K1: ON ^KEYLIGHT ---> S3
```

```
S3,    \ K2 SENT BY CONTROL BOX WHEN RF STARTS
  #K2: OFF ^KEYLIGHT; ON ^FEEDER ---> S4

S4,
  4": OFF ^FEEDER ---> S2
```

K-Pulse Theory Of Operation And Technical Details

When a K-pulse is issued, it is not immediately available as an input to statements, and does not become available to other statements and boxes until the beginning of the next interrupt (the next time boxes are serviced). For illustrative purposes assume that the system resolution is set to 10 ms and the control procedure is running in box 1 and the yoked box is running in Box 2. When the control box issues K1, the K1 is entered into a queue (a waiting list). Although Box 2 will be serviced immediately after Box 1 (within a millisecond), the K1 will not be presented to Box 2. Instead, when the next interrupt occurs, about 10 ms later, the K1 is removed from the queue and made available to both Boxes 1 and 2 and Box 2 will then react to the K1. Stated succinctly, K-pulses are placed in a queue until the next processing sweep (interrupt) occurs.

If more than one box issues the same K-pulse within the same processing sweep, only one K-pulse will be issued. For example, if Box 1 is counting the number of K1 pulses that occur and Boxes 2 and 3 simultaneously issue K1, Box 1 will detect only 1 K-pulse. Similarly, if the same K-pulse is issued several times within the same output statement, the net effect will be the same as if the K-pulse was issued only once. For example, 1":K1; K1 ---> SX is equivalent to 1": K1 ---> SX.

When a Box issues a K-pulse, it is available to all active boxes on the next processing sweep. Also, a Box may react to one of its own K-pulses. The following procedure could both issue and count the occurrence of K1.

```
S.S.1,
S1,
  1": K1 ---> SX


S.S.2,
S1,
  #K1: ADD A; SHOW 1,K1CNT,A ---> SX
```

K-pulses should not be used in place of Z-pulses; although superficially similar, these commands have different purposes. K-pulses are used for communication between boxes, whereas Z-pulses are designed for communication between state sets within boxes. K-pulses have the same priority level as normal MSN commands. Unlike Z-pulses, K commands are treated as normal inputs in the sense that when K's are "stacked" with other commands, the topmost statement will be processed in the event of a tie. For example, in the following code, in the event of a simultaneous #K1 and #R1, transition would be to S2:

```
#K1 ---> S2
#R1 ---> S3
```

Processing Efficiency of the K-pulse

As noted above, do not treat K-pulses as interchangeable with Z-pulses. One reason for this concern is that issuing a K-pulse from within an MSN procedure generates a considerable amount of overhead because each box must be processed to determine whether the occurrence of the K-pulse necessitates any transitions between states. When a K is issued from the keyboard, it is not presented simultaneously to all boxes. Instead, the operator specifies a list of one or more boxes to receive the K. Furthermore, WMPC automatically spaces the delivery of keyboard K's across boxes to help distribute the processing load. This is in contrast to the situation when K's are issued from an MSN procedure, in which case the K is issued simultaneously to all boxes; hence, issue K-pulses from within MSN procedures sparingly. This is not to discourage their use, but rather to point out that they should not be used with abandon.

The Special Variable "BOX"

It is often desirable to have an MSN procedure react to K-pulses conditionally upon which box issued the K-pulse. Consider the yoked auto-shaping paradigm presented above. In that example, the control box issues K1 and K2 to indicate to the yoked box the occurrence of critical events. As long as only one box is running the control procedure and only one is running the yoked procedure at any given time, everything will work fine. Consider, though what would happen if Boxes 1 and 3 were simultaneously running the control procedure while Boxes 2 and 4 were running the yoked procedure. Whenever a stimulus change would occur in Box 1 or 3, stimulus changes would occur in both Boxes 2 and 4; the two yoked boxes would each be yoked to two control boxes. One way around this problem would be to write separate a control procedure for box 1 that issues K1 and K2 and a different control procedure for Box 3 that issues K3 and K4. This solution would work, but would require writing and maintaining multiple copies of essentially the same procedure.

A more elegant solution to this problem is to adjust the number of the K-pulse on the basis of which box is issuing or receiving the K-pulse. In the following example, the yoked auto shaping code has been modified so that Box 1 will issue K1 and K2, whereas Box 3 will issue K3 and K4 to communicate with Box 4. This is accomplished by incorporating a special variable named "BOX" into commands that receive and issue K-pulses. BOX is always equal to the box number of the box in which the MSN program is running. In the control procedure in the following code example, the K-pulse in state 2 would be K1 when the procedure is running in Box 1 because BOX would equal 1. Similarly, when running in Box 3, the same statement would issue K3. In the yoked procedure, K (BOX - 1) would respond to K1 (issued by Box 1) when running in Box 2 because BOX would equal 2. When running in Box 4, the yoked procedure would respond to K3 (Box 3's first K-pulse). By alternating between Control and Yoked boxes any number could run the same procedure.

```
\ Modified auto shaping code demonstrating use of the "box" variable

\ Auto shaping procedure for the "control" box

^FEEDER=1
^HOUSELIGHT=2
^KEYLIGHT=3

S.S.1,
S1,
#START: ON ^HOUSELIGHT ---> S2

S2,    \ 20" mean tell yoked box when it is over by sending a k-pulse
       \ equal to this box's box number
  1": WITHPI = 500 [ON ^KEYLIGHT; K BOX] ---> S3

S3,    \ Tell yoked box that feeder is on by sending K2
  #R1 ! 8": OFF ^KEYLIGHT; ON ^FEEDER; K(BOX + 1) ---> S4
            \ End a K with a number 1 more than this box's box number

S4,
  4": OFF ^FEEDER ---> S2

======================================================

\ Auto shaping procedure for the "yoked" box

^FEEDER=1
^HOUSELIGHT=2
^KEYLIGHT=3

S.S.1,
S1,
  #START: ON ^HOUSELIGHT ---> S2

S2,    \ K1 sent by control box when KEYLIGHT turned on
  #K(BOX - 1): ON ^KEYLIGHT ---> S3
               \ Look for the first K of the preceding box

S3,    \ K2 Sent by control box when RF starts
  #K BOX: OFF ^KEYLIGHT; ON ^FEEDER ---> S4
          \Look for the second k of preceding box

S4,
  4": OFF ^FEEDER ---> S2
```

Turning the PC's Speaker on and off:

ALERTON

ALERTON produces a 500 Hz tone via the PC's speaker. The tone is alternately on and off for 500 ms. If multiple boxes issue ALERTON, a single alternating tone is produced; one cannot identify the number of boxes that have issued the ALERTON.

ALERTOFF

ALERTOFF cancels the tone. A single ALERTOFF cancels the tone until the next ALERTON. Thus, several boxes could issue an ALERTON, but a single ALERTOFF would entirely eliminate the tone.

A common use for ALERTON will be to signal the end of a session as follows:

```
S.S.1,
S1,
  10#R1: ON 1 ---> S2

S2,
2": OFF 1 ---> S1


S.S.2,
S1,
30': ALERTON ---> S2

S2,
#K1: ALERTOFF ---> SX
```

ALERTON may only be turned on from within an MSN procedure, but ALERTOFF may either be issued from within a procedure or by using a functionally equivalent command from the runtime menu system. It is also possible to produce beeps whenever all boxes are shut off by enabling the "Tone Alert When Done" toggle within the runtime menu system. The beeps produced by this menu selection are functionally equivalent to those produced by ALERTON, and may be canceled either from the menu or by ALERTOFF. See Chapter 2 of the WMPC User’s Manual for detailed procedures on the use of these commands from the runtime menu system.

Even if inline Pascal code is used to produce tones, it is still possible to simultaneously use the ALERTON/ALERTOFF features. Note that ALERTON is easier to use than inline Pascal-produced beeps because it is unnecessary to handle timing or other details of producing beeps. Additionally, the beeping will persist even when all boxes are unloaded.

The duration of beeps produced by ALERTON may show considerable variation and may temporarily be suspended during some especially time-intensive menu tasks. This is especially likely to happen while writing files to disk. As soon as disk writing is finished, the beeping will resume.

Mathematics Output Commands:

ADD

ADD is generally used to increment a variable or array element by 1. It performs the same function as SET A = A + 1.

Syntax: ADD P1

Where: P1 = variable or array element

Comments: Stringing Variables with Comma separation permissible

Examples:

```
S1,
  1": ADD C ---> SX                    \ Every second add 1 to the value
                                       \ of C
  #R2: ADD X, Y, Z, A(I) ---> SX       \ Every response from input 2 add 1
                                       \ to the value of variables X, Y, Z
                                       \ and array element A(I)
```

SUB

SUB is used to decrement a variable or array element by 1. It performs the same function as SET A = A - 1.

Syntax: SUB P1

Where: P1 = variable or array element

Comments: Stringing Variables with Comma separation permissible

Examples:

```
S1,
  1": SUB C ---> SX                  \ every second subtract 1 from the
                                     \ value of C
#R2: SUB X, Y, Z, A(I) ---> SX       \ Every response from input 2
                                     \ subtract 1 from the value of
                                     \ variables X, Y, Z and array element
                                     \ A(I)
```

SET

SET is used to perform any of four basic mathematical operations involving two or more operands. Any mathematical function provided by Turbo Pascal can also be inserted within a MSN statement using In-Line Pascal (See Appendix B). Two forms of this command are possible as indicated by syntax A and syntax B.

Four "Operators" are permitted:

/	(Division)
*	(Multiplication)
+	(Addition)
-	(Subtraction)

Syntax A: SET P1 = P2 Operator P3

Syntax B: SET P1 = P2

Where: P1 = variable or array element

P2 and P3 = number, variable, or array element

Operator = /, *, +, or -

Comments: Stringing is permissible

P2 and/or P3 may be followed by " or ' to assign a time value to a variable or array element.

Assigning a new value to a constant is not permissible. It will not produce a TRANS20 error but will produce a TPC error during compilation, typically of the form "Undefined Label".

In the original MED-PC, complicated math expressions had to be broken into pieces. For example "SET A = 1+2*10/4-3" may have been written, "SET A = 2 * 10, A = A / 4, A = A - 2". Since Version 2.0 of MED-PC (DOS), complex expressions can be written directly; this example is now written as "SET A = 1 + ((2 * 10) / 4) - 3".

Examples:

```
1': SET A = 5 * A, C = B(K) ---> SX
#R3: SET A= (5 * A) + B + C ---> SX    \ Note: multiple operations
```

BIN

BIN is an output command that can be used to generate frequency distribution as data is collected. The frequency distribution is output into a range of array elements specified in the call to BIN. The width of each "Bin" in the frequency distribution is user controllable. The first "bin" always contains the total frequency, or total number of all categorized events, and the second bin always contains the total number of events with values greater than that represented by the last "bin." Like any array, the BIN data array must be dimensioned prior to State Set 1.

Syntax: BIN P1, P2, P3, P4, P5, P6

Where: P1 = Array which will hold the frequency distribution.

P2 = A variable or array element containing the number to be added to the frequency distribution.

P3 = The units of P2. If one is recording time, then P3 is how frequently P2 is incremented.

P4 = The width of each bin or cell of the distribution.

P5 = Array element, variable, constant, or number denoting the first counter or array element containing the BIN distribution. It is also the element into which the total frequency will be recorded.

P6 = Array element, variable, constant, or number denoting the last counter or array element into which the BIN distribution is recorded.

Example:

```
^START = 0
^END = 10

DIM C = 10

S.S.1,
S1,
  #R1: BIN C, A, .1, 5, ^START, ^END; SET A = 0 ---> S1
  .1": ADD A ---> SX
```

In this example, the frequency distribution is recorded into array C from element C(0) through element C(10). C(^START) marks the first element of the distribution and will also contain the total frequency recorded, i.e., C(^START + 1) + C(^START + 2) +...+ C(^END). A is a variable containing the current value to be categorized. Values greater than the category assigned to C(^END) are placed in C(^START + 1), the second element in the BIN array. The .1 indicates that the data are being recorded with 0.1" resolution and the 5 indicates that each BIN is to be five seconds wide. Given the values above and a subject that responds 50 times with IRT's between 0.1 seconds and some indeterminate maximum, the following data array might result:

ELEMENT	BIN RANGE IN SECONDS	RESPONSES
C(0)	Total Responses	50
C(1)	Greater than 45	3
C(2)	0 - 5	3
C(3)	5.1 - 10	5
C(4)	10.1 - 15	7
C(5)	15.1 - 20	8
C(6)	20.1 - 25	9
C(7)	25.1 - 30	6
C(8)	30.1 - 35	4
C(9)	35.1 - 40	3
C(10)	40.1 - 45	2

The aforementioned example serves to "BIN" inter-response times. Sometimes it is desirable to "BIN" a response count by the elapsed time. The following example illustrates this with an FI20 schedule. Note: this does not require the BIN command.

```
\ Sample program showing how to create incremental "Bins."

\ C = Array storing the number of responses in 5 minute bins
\ D = Experiment Duration with default value 60 minutes
\ I = Index into the array

DIM C = 200    \ Arbitrary value.  In this example only 13 elements
               \ (0 - 12) are used, one for total response count plus
               \ 12 five minute bins.

S.S.1,    \ Increment Response count in C(0) plus bin C(I)
S1,
  .01": SET D = 60, I = 1 ---> S2

S2,
  #START: SHOW 1,BIN,I, 2,BinCnt,C(I), 3,TotCnt,C(0) ---> S3
  1": SHOW 1,BIN,I, 2,Sess_n,D ---> SX

S3,    \ Response Count and Display
  #R1: ADD C(0), C(I); SHOW 2,BinCnt,C(I), 3,TotCnt,C(0) ---> SX


S.S.2,    \ Increment to the Next Counter Every 5 Minutes.  Use a
          \ variable and #T for a more flexible program.  See S.S.3.
S1,
  #START: SET C(I + 1) = -987.987 ---> S2

S2,
5': ADD I; SET C(I) = 0, C(I + 1) = -987.987;
    SHOW 1,BIN,I, 2, BinCnt, C(I) ---> SX


S.S.3,    \ End the Session After D amount of Time
S1,
  #START: SET D = D * 1' ---> S2

S2,
  D#T: ---> STOPABORTFLUSH
```

LIMIT - Increment or Decrement to a Bound

This function may be used to increment or decrement a variable. Importantly, a limit is specified beyond which the variable will not be incremented or decrement. This function should be used when it is specifically desired to limit the value of a variable; it should not be used as an alternative to ADD, SUB or SET in cases where those functions will suffice. The processing overhead or performance penalty associated with LIMIT is somewhat higher than that associated with the alternative functions. This is not to say that LIMIT should not be used when necessary, but rather that it should not be used indiscriminately.

Syntax: LIMIT P1, P2, P3

Where: P1 = Variable or array element to be incremented or decremented. It may not be a constant or a fixed number.

P2 = A variable, array element, constant or number specifying the numerical value by which P1 will be incremented or decremented each time LIMIT is executed.

P3 = The maximum or minimum value of P1. Once reached this value will be held no matter how many times LIMIT is executed.

```
S.S.1,    \ This code fragment adds 2 to X every second.
S1,       \ X will achieve and hold a value of 10.
  1": LIMIT X, 2, 10 ---> SX
```

```
S.S.1,    \ This code fragment adds 3 to X every second.
S1,       \ X will achieve and hold a value of 9.
  1": LIMIT X, 3, 10 ---> SX
```

```
S.S.1,    \ This code fragment subtracts 1 from X every second.
S1,       \ X will achieve and hold a value of -5.
  1": LIMIT X, -1, -5 ---> SX
```

Decision Functions:

IF

IF permits the values of two numeric parameters, a numeric parameter and a variable, or two variables to be compared. Several syntaxes are permissible.

Six comparisons "Operators" are permitted:

=	(Equals)
<	(Less Than)
<=	(Less Than or Equal To)
>	(Greater Than)
>=	(Greater Than or Equal To)
<>	(Not Equal To)

Syntax A:

```
IF P1 Operator P2 [@Label1, @Label2]
   @Label1: Output Section ---> Transition
   @Label2: Output Section ---> Transition
```

Syntax B:

```
IF P1 Operator P2 [@Label1]
   @Label1: Output Section ---> Transition
```

Syntax C:

```
IF P1 Operator P2 [Output Section] ---> Transition
```

Where: P1 & P2 = Constant, number, variable, array element, or special identifier as described below.

Label1 & Label2 = Any text label containing only letters.

Output Section = Any legal output command(s).

Transition = Any legal Transition such as SX, STOPABORT, STOPKILL, or S1...S32 (given that S1...S32 is a valid state within the same state set)

Comments: Unlimited nesting is permissible. The three syntax variations may be freely intermixed when nesting. Labels are arbitrary, and need not match, but must begin with @.

Examples and Discussion:

Example A:

Because labels are arbitrary, spelling does not need to be consistent. If the comparison evaluates as TRUE, then the following statement (on the next line) is executed. If the comparison is FALSE, then the statement two lines down is executed.

```
S.S.1,
S1,
  #R1: ADD A; OFF1; ON2 ---> S2

S2,
  2": OFF2; IF A = 100 [@True, @False]
              @True: ---> STOPABORT
              @False: ON1 ---> S1
```

```
S.S.1,
S1,
  #R1: ADD A; OFF1; ON2 ---> S2

S2,
  2": OFF2; IF A = 100 [@True, @False]
              @True: ---> STOPABORT
              @F: ON1 ---> S1
              \ @FALSE and @F are not required to match.
```

The legal examples above illustrate a situation in which a #R1 increments a reinforcement counter, turns off a stimulus light, turns on a feeder and goes to S2. After 2", the feeder output is turned off and variable A (the reinforcement counter) is tested. If the value of A is now 100 then the statement associated with the label @True is executed and the procedure terminates. If the value is less than 100, the statement following the label @False is executed (the stimulus is turned ON and transition takes place back to S1).

Example B:

When a label is in the input section of a statement, a colon (:) must follow it, even when there is no output section to the statement.

Illegal Examples:

```
S.S.1,
S1,
  #R1: ADD A; OFF1; ON2 ---> S2

S2,
  2": OFF2; IF A = 100 [@True, @False]
              @True ---> STOPABORT    \ Missing ":" after label
              @False: ON1 ---> S1
```

Example C:

Careful attention to proper syntax is important, for certain errors are not detected by WTRANS and will result in compiler errors. An error which WTRANS does not detect but which will cause programs to malfunction is to have a transition arrow after the first label. For example:

```
1": IF A [@TRUE, @FALSE] ---> S2
```

Example D:

Although not permitted by earlier versions of MPC, IF statements may be nested more than one deep. In the following example variables A, B and C are all tested with respect to Variable X. If all three are greater than or equal to X then transition is to State 2. If any variable fails the test then transition is to State 3.

```
S.S.1,
S1,
  1": IF A >= X [@FirstTrue, @FirstFalse]
         @FirstTrue: IF B >= X {@SecondTrue, @SecondFalse]
                        @SecondTrue: IF C >= X [@ThirdTrue,@ThirdFalse]
                                        @ThirdTrue: ---> S2
                                        @ThirdFalse: ---> S3
                        @SecondFalse: ---> S3
         @FirstFalse: ---> S3
```

The labels used with the IF command are arbitrary. For example, in the above example if A >= X is false then execution immediately drops down to the statement on the same tab, regardless of whether @FirstFalse is properly spelled. It is, however, mandatory to use a label. Also, a colon must follow the label, even if there is no output section, as in "@FirstFalse: ---> S3."

Example E:

A variation on the IF command is to specify only the true alternative. If the conditions tested by the IF are not met, then transition to SX automatically occurs without being stated. This is illustrated with Example B.

```
S.S.1,
S1,
  10": ADD A; IF A = 10 [@GO]
                 @GO: ON 1 ---> S2

S2,
  .1": SET A = 0; OFF 1 ---> S1
```

In Example E, no transition will take place in state 1 until A is equal to 10. When A = 10 is true, transition to state 2 will occur.

Example F:

A final variation on the syntax permits labels for true and false conditions to be omitted. When this syntax is used, output commands are enclosed in square brackets following the logical comparison. If the logical comparison is TRUE then the commands enclosed in the brackets are executed and the transition indicated to the right of the arrows is executed. If the logical comparison is FALSE then transition to SX automatically occurs. This is illustrated by the following:

```
S.S.1,
S1,
  10": ADD A; IF A = 10 [ON 1] ---> S2

S2,
  .1": SET A = 0; OFF 1 ---> S1
```

Example F functions equivalently to Example E. This format requires a pair of square brackets, even if they enclose nothing. For example:

```
S.S.1,
S1,
  10": ADD A; IF A = 10 [ ] ---> S2
```

Compound IF Statements

IF statements may be constructed such that several logical conditions must be met in order for the expression to evaluate as TRUE. This may be accomplished by placing each set of logical criteria in parentheses and connecting each set with AND, OR, NOT, AND NOT, or OR NOT. Parentheses serve to denote the order in which expressions are evaluated, in much the same way that parentheses control execution of algebraic expressions in SET statements. Logical expressions are always evaluated first within the deepest level of parentheses.

Examples:

In the following expression, output 1 is turned on only if A equals 1 and B equals 2.

```
#R1: IF (A = 1) AND (B = 2)[ON 1] ---> S2
     \Note that each term "A = 1" and "B = 2"
     \are enclosed in parentheses ().
```

In the following expression, output 1 will be turned on if either X + 3 equals 10, or if A equals 1 and B equals 2. Of course, if all three conditions are met, output 1 will also be turned on.

```
#R1: IF (X + 3 = 10) OR ((A = 1) AND (B = 2)) [ON 1] ---> S2
```

This example also demonstrates the use of mathematical expressions within IF statements. Whenever writing IF statements in which parenthetical expressions are used, be sure that the number of left and right parentheses are equal. Parentheses must be used whenever more than one logical condition is being tested.

The following are examples of illegal tests, followed by correct examples:

1)

```
A = 1 OR B = 2          \ Illegal -- no parentheses
(A = 1) OR (B = 2)      \ Legal
```

2)

```
A = 1) OR (B = 2        \ Illegal - unequal number of parentheses
(A = 1) OR (B = 2)      \ Legal
```

3)

```
A = 10 OR 5              \ Illegal - each comparison must have 2 terms
(A = 10) OR (A = 5)      \ Legal
```

Special Identifiers

P1 and/or P2 may be a special identifier as listed below. One special identifier reflects the specified state set's current state, and is represented by "S.S.#". Never alter the value of this variable. Other special identifiers may be used in expressions in the same way that any variable or array element may be used. For example, they may participate in logical tests with IF statements, be part of assignments with SET, and may serve as prefixes or suffixes to #K, #R, #Z, etc. WMPC does not prevent one from changing the value of these identifiers with a SET command, but do so only with caution. These variables are also available for use in inline PASCAL expressions. A complete list of the variables that may be queried follows the "Examples and Discussions" section:

Examples and Discussion:

Example A:

```
1": IF S.S.3 = 5 [ON 1] ---> S2
```

The IF command makes a logical comparison on the basis of whether State Set 3 is currently in State 5. If the comparison is true output 1 is turned ON and a transition is made to State 2. A complete list of special identifiers will be found at the end of this section, following the WITHPI command.

WITHPI

WITHPI is a probability gate that samples with replacement. WITHPI functions much like an IF statement, but truth or falsity of decisions depend upon probabilistic decisions. As with IF, it may be used with three different syntaxes. Probabilities are always specified as chances out of ten thousand.

Syntax A:

```
WITHPI = P1 [@Label1, @Label2]
        @Label1: Output Section ---> Transition
        @Label2: Output Section ---> Transition
```

Syntax B:

```
WITHPI = P1 [@Label1]
        @Label1: Output Section ---> Transition
```

Syntax C:

```
WITHPI = P1 [Output Section] ---> Transition
```

Where: P1 = Constant, number, variable, or array element.

Label1 & Label2 = Any text label containing only letters.

Output Section = Any legal output command(s).

Transition = Any legal Transition such as SX, STOPABORT, STOPKILL, or S1...S32 (given that S1...S32 is a valid state within the same state set).

Comments: Nesting is permissible using the first Syntax.

Stringing is not permitted.

Labels are arbitrary but must begin with @.

When a label is in the input section of a statement, it must be followed by ":" even when there is no output section to the statement.

Examples and Discussion:

Example A:

Because labels are arbitrary, spelling does not need to be consistent. If the probability gate evaluates as TRUE, then the following statement (on the next line) is executed. If the probability gate is FALSE, then the statement two lines down is executed.

```
S.S.1,
S1,
  #R1: WITHPI = 5000 [@Reinforcement, @No Reinforcement]
                @RF: ON1 ---> S2
                @NORF: ---> SX

S2,
  2": OFF1 ---> S1
```

In Example A, every response in state 1 has a pseudo-randomly determined probability of 5000/10000 (50%) of causing transition to the true alternative (@RF) in which case reinforcement is delivered and transition to State 2 will occur.

Changing the parameter from 5000 to 1000 would specify that response 1 would have a 10% (1000/10000) probability of resulting in transition to State 2.

Example B:

An error which WTRANS does not detect but which will cause programs to malfunction is to have a transition arrow after labels. For example:

```
1": WITHPI = 1000 [@TRUE, @FALSE] ---> S2
```

LISTING OF SPECIAL IDENTIFIERS

BOXNUMBER and BOX

These identifiers are synonymous and reflect the box number of the box in which the MSN procedure is executing. BOX may be especially useful in conjunction with inter-box communication (see section on inter-box K-pulses). Under no circumstances should these values be altered with a SET command.

SUBJECTNUMBER, EXPNUMBER and GROUPNUMBER

These reflect the subject, experiment and group numbers of the subject in the box in which the experiment is executing. These values may be safely altered with a SET command but be aware that the box's status line on the runtime screen will not be automatically updated to reflect changed values.

STARTMONTH, STARTDATE, STARTYEAR, STARTHOURS, STARTMINUTES and STARTSECONDS

These reflect the date and time at the moment when the current box was loaded with the "Open Session" menu selection. They are equal to the values displayed on the runtime screen on the box's status line. STARTYEAR is a 2-digit number reflecting the last 2 digits of the year. For example, in 1991, STARTYEAR will equal 91 [9]. Note, the use of the term start in this context bears no relationship to the issuance of a #START command from the keyboard. Procedures actually "start" the instant they are loaded. These values may be safely altered with a SET command but be aware that the box's status line on the runtime screen will not be automatically updated to reflect changed values.

ENDMONTH, ENDDATE, ENDYEAR, ENDHOURS, ENDMINUTES and ENDSECONDS

These variables are set equal to the date and time when the box's execution is terminated with KILL, ABORT or ABORTFLUSH. During procedure execution these variables are normally equal to 0. These values may be altered during procedure execution with a SET statement, but when procedure execution terminates, they will be automatically changed to the date and time of termination.

---

[9] You must use a four-digit date if the Y2KCOMPLIANT command is used in your code. For a discussion on this command, see the "Commands that come before the first state set" section of this Appendix.

CURRENTMONTH, CURRENTDATE, CURRENTYEAR, CURRENTHOURS, CURRENTMINUTES, and CURRENTSECONDS

These variables reflect the date and time at approximately the time they are accessed in an expression. It is important to recognize that CURRENTSECONDS is not a precise reflection of the present time. Under some circumstance, this variable (and all other CURRENT variables) may be a few seconds behind the actual value of the DOS clock because their values are updated only as WMPC has spare time remaining after servicing boxes. These values are in no way related to the internal timing of experimental events; experimental events are timed independently of the DOS clock. For precise access to time, utilize BTIME. These values may be altered but it is pointless to do so because WMPC will automatically correct them within a few seconds of their alteration.

SECSTODAY

This variable is a single variable that contains the cumulative number of seconds past midnight. SECSTODAY is subject to the same accuracy limitations as CURRENTSECS. SECSTODAY is useful for recording the approximate (accurate to within a few seconds) time of day when an event occurs. It is no more or less accurate than CURRENTHOURS, CURRENTMINUTES and CURRENTSECONDS, but does allow one to condense the information contained in those three variables into a single number. This allows one to record the time of occurrence of events in a minimum number of array locations. Subsequent data analysis software could be used to reconstruct hour, minute and second information.

DATETODAY

DATETODAY is a single number that condenses CURRENTYEAR, CURRENTMONTH and CURRENTDATE into a single number in the format YYMMDD. For example, June 2, 1990 would be expressed as 900602.

BTIME

This number is based upon MED-PC's internal timer interrupt system. BTIME is used internally to time experimental events. BTIME is set to 0 when WMPC is loaded and continues to increment throughout the session every time an interrupt occurs. BTIME increments 1000/RESOLUTION times per second, where RESOLUTION is the timing resolution declared during installation. On a 50 ms system, BTIME increments 20 times per second. On a 20 ms system, BTIME increments 50 times per second.

BTIME may be useful for recording elapsed times, but there is no particular advantage to this technique over recording elapsed time by incrementing a WMPC variable on a periodic basis with conventional MSN timing statements.

BTIME must never be altered.

Array Functions:

Data that has been entered into arrays via a LIST declaration may be accessed via the commands LIST, RAND and RANDI. LIST successively draws values from an array, RANDI randomly selects with replacement from an array, while RANDD selects without replacement from an array.

LIST

List is first placed before State Set 1 to dimension an array and assign a value to each element in an array. It can then be used in the output section of a statement to select each value in sequence. When the last element in the list has been used, selection restarts at the beginning of the list.

Syntax A: Defining the array

```
LIST P1 = P2, P3,...,Pn
```

Where: P1 = Array

```
P2, P3,...,Pn = Number
```

Comments: Array elements take up a larger amount of memory than one would think. Therefore, there is a limit on the number of characters (2550) per statement

Up to 10 Lines are permissible.

Each line, up to 255 characters, long must end on a comma <CR>.

Syntax B: Selecting elements from the array.

```
LIST P1 = P2 (P3)
```

Where: P1 = variable or array element

P2 = array from which an item is to be drawn

P3 = variable or array element used as subscript to array P2

Comments: Stringing is permissible

The value of P3 is automatically incremented by the LIST command. Assignments to P3 through other commands will affect the selection of subsequent items via the LIST command (i.e. it is possible to skip or retrace elements in the array via manipulation of the P3 subscript.) This must be done with caution, however, as an illegal subscript value will be ignored by WMPC, reverting your array back to subscript zero.

Array P2 may be declared with LIST or DIM statement.

Examples and Discussion:

Running the following procedure would result in the following pattern of outputs: 1, 2, 3, 1, 2, 3, 1, 2, 3,...

Example A:

```
LIST A=1, 2, 3

S.S.1,
S1,
  1": LIST B = A(K); ON B ---> S2

S2,
1": OFF B ---> S1
```

In the first LIST statement above, an array named A is declared. The lowest element of an array is always referenced as Element 0. Element 0 contains the value 1, Element 1 contains the value 2 and Element 2 contains the value 3.

One second after this procedure is loaded, the statement "LIST B = A(K)" sets B equal to the value of element K of array A. Since all variables are automatically set to 0 at the beginning of program execution, the value of B is set equal to A(0) and ON B causes output 1 to be turned ON. One second later, output 1 is turned OFF in State 2. Following assignment of the value of A(K) to B, 1 is automatically added to the value of K so that the next time the list statement is executed, the array index (K) for array A is equal to 1 giving B a value of 2 to turn ON output 2.

The LIST command continues to select successive array elements until the end of the list is reached. When the last element has been accessed, the array index (K) is reset back to 0.

Example B:

```
LIST A:  5, 10, 15, 20, 25, 30,    \note that each line
        30, 35, 40, 45, 50, 55,    \must end in a comma
        60, 65, 70, 75, 80, 85     \except for the last one.
```

RANDD

RANDD is similar to LIST except that it selects values from a previously defined array without replacement. A major difference, however, is that no subscript is specified with this command. Again, all elements in the array are drawn before any element is repeated. RANDD can only operate on arrays declared in a LIST statement.

Syntax:

```
RANDD P1 = P2
```

Where: P1 = variable or array element

P2 = array from which an item is to be drawn

Comments: Stringing of parameters is permissible.

Array P2 must be declared with a LIST statement.

The maximum number of elements that may be in an array manipulated by RANDD is 501 (elements 0...500).

The order of the contents of P2 is not affected by RANDD Selection actually takes place from an internal copy created and managed automatically by WMPC.

Example:

Items are randomly selected from the LIST, however once selected an item is removed from the list until all items have been selected. This is selection without replacement. The following state set might turn outputs on in the following order: 1, 2, 3, 2, 3, 1, 2, 1, 3, 3, 1, 2,...

```
LIST A=1, 2, 3

S.S.1,
S1,
  1": RANDD B = A; ON B ---> S2

S2,
  1": OFF B ---> S1
```

RANDI

RANDI is similar to RANDD in that it selects values from a list. Again, no array subscript is specified. RANDI randomly draws with replacement from an array, however, so elements can be repeated and may not occur an equal number of times (unless run over a long period of time). RANDI can only operate on arrays declared in a LIST statement.

Syntax:

```
RANDI P1 = P2
```

Where: P1 = variable or array element

P2 = array from which an item is to be drawn

Comments: Stringing of parameters is permissible.

Array P2 must be declared with a LIST statement.

The maximum number of elements that may be in an array manipulated by RANDI is 501 (elements 0...500)

The order of the contents of P2 is not affected by RANDI Selection actually takes place from an internal copy created and managed automatically by WMPC.

Example:

The actual order of selection is totally random. A single item may be selected more than once even though some items have not been selected. This is selection with replacement. The following order of outputs might occur: 3, 1, 1, 2, 1, 3, 2, 2, 1, 3,...

```
LIST A=1, 2, 3

S.S.1,
S1,
  1": RANDI B = A; ON B ---> S2

S2,
1": OFF B ---> S1
```

COPYARRAY

COPYARRAY is an output command that may be used to transfer the contents of one array to another. This command simplifies and speeds the transfer of data between arrays and can be used to move an entire array to a "buffer array" for saving while continuing to collect data. Copying the contents of one array to another is particularly useful for continuous running applications.

COPYARRAY takes three arguments: the source array from which data are to be copied, the target array to which data will be copied, and the number of elements of the source to copy to the target. Copying always starts with the first element of the source array (element 0) and data are always placed into the target array starting at element 0 of the target. The number of elements of the source array that are copied should never exceed the size of the target array. If an attempt is made to copy too many elements to the target array, a WMPC runtime error message will be generated.

Syntax:

```
COPYARRAY P1, P2, P3
```

Where: P1 = The source array from which data will be copied.

P2 = The array into which data will be copied.

P3 = The number of elements of P1 to copy to P2.

P1 & P2 must be the name of an array.

P3 may be a variable, constant, number, array element, or mathematical expression.

Example:

In the following example, the current cumulative response totals on inputs 1-3 are transferred from array A to array B every 5' and then printed. This technique ensures that all data are printed from the same moment (see description of PRINT command).

```
DIM A = 2
DIM B = 2
PRINTVARS = B

S.S.1,
S1,
  #R1: ADD A(0) ---> SX
  #R2: ADD A(1) ---> SX
  #R3: ADD A(2) ---> SX


S.S.2,
S1,
  5': COPYARRAY A, B, 3; PRINT ---> SX    \FROM A to B COPY 3 Elements
                                          \(0,1,2) AND THEN PRINT
```

ZEROARRAY

This command sets all of the elements of an array to 0. The command takes the name of the array to zero as its only argument.

Syntax:

```
ZEROARRAY P1
```

Where: P1 = Must be the name of an array declared by LIST or DIM.

Example:

```
S.S.2,
S1,
  5': COPYARRAY A, B, 3; ZEROARRAY A; PRINT ---> SX
```

The above uses the same S.S.2 from the COPYARRAY example; however, this time the counter in array A are also zeroed every 5'.

GETVAL

GETVAL is an output command that may be used to get the value of a variable or array element in another box. This command is useful in situations in which it is necessary for one box to monitor the status of another box. This situation may arise when conducting experiments on yoked subject pairs. (See use of K-pulses and the special variable named "BOX").

Syntax:

```
GETVAL P1 = P2, P3
```

Where: P1 = The variable or array element in the present box to be set.

P2 = The box number from which a datum is requested.

P3 = The variable or array element whose value is being read.

Example:

```
S.S.1,
S1,
  1": GETVAL A = 2, B ---> SX     \ Set A equal to the value of
                                  \ variable B in Box 2
```

Sometimes it is desirable to get a variable value from a prior day's run for the same box. See Appendix B for an advanced programming technique to call User.pas for this propose.

Data Handling Commands:

SHOW

SHOW may be used to display data on the screen while a procedure is running. Each SHOW command takes three arguments. The first is the screen position (1-60), the second is the 6-character label, and the third is a number, variable or constant to be displayed on the screen. Each of up to 12 procedures may independently display the values of up to 60 variables along with descriptive labels on the screen. See the WMPC User's Manual for full details on how these are displayed on the screen.

Syntax:

```
SHOW P1, P2, P3
```

Where: P1 = whole number in range 1..60 expressed as an array element, variable, constant, or number.

P2 = a one to six character description that may not resemble a MedState Notation command (e.g., TIME, DATE, etc).

P3 = number, variable, constant, array element, or mathematical expression.

Comments: There may be up to sixty SHOW's per Box.

The SHOW command is a secondary function and may be delayed while boxes are processed, data saved, or sent to print manager.

Stringing is permissible.

Example A:

The following example displays the label "XValue" in the tenth position on the SHOW screen (last position in the second line of the SHOW area). Every second the value of X will increment by one and will be reflected on the screen.

```
S.S.1,
S1,
  1": ADD X; SHOW 10,XValue,X ---> SX
```

Example B:

This example illustrates stringing of parameters in SHOW, the use of a constant value (5.01), the constant "^ThisValue" and a mathematical expression.

```
^ThisValue = 5

LIST A = 2, 5

S.S.1,
S1,
  1": SHOW 1,Value1,5.01, 2,Value2,^ThisValue, 3,Math,A(0)+A(1) ---> SX
```

When loaded to box 1 this example creates the following display:

1) VALUE1 5.01 VALUE2 5 MATH 7

Numeric Format of SHOW Output

Numbers are normally displayed in a "7.2" format, meaning that there is room for 4 digits to the left and 2 to the right of the decimal point. This allows for numbers up to 9999.99 to be displayed with 2-digits of decimal precision. If, however, the number exceeds 9999.99, then decimal positions and the decimal point will be successively dropped so that a number as large as 9999999 may be displayed (with no decimal digits).

Updating the SHOW Display

SHOW commands are not displayed in real-time. When a box issues a SHOW command, the data values are retained, but the data will not actually be displayed until the runtime system has time to update the screen. The values eventually shown on the screen will reflect the values of their respective variables at the moment that their respective SHOW commands were issued. In practice, the SHOW screen is usually updated within a small fraction of a second after any changes are made by active boxes; most users would probably not even notice that updates are not in "real-time" except in the case of displaying running response totals for rapidly-responding subjects, in which case the response total shown on the screen will discontinuously count up. For example, a pigeon responding in a box controlled by the following code would most likely produce SHOW output that appears on the screen as a discontinuously incrementing counter (perhaps incrementing as 3,7,8,12, etc.):

Example A:

```
^FEEDER=5

S.S.1,
S1,
  20#R1: ADD Y; SHOW 2,RFS,Y; ON ^FEEDER ---> S2

S2,
  2": OFF ^FEEDER ---> S1


S.S.2,
S1,
  #R1: ADD X; SHOW 1,RESPS,X ---> SX
```

Example B:

In the above sample, the displays are not present until the animal begins responding (SHOW1) or responds 20 times (SHOW2). Show Labels may be displayed even while variable values are zero to confirm that a program is running with the following changes to the above code.

```
S.S.1,
S1,
  #START: SHOW 1,RESPS,X, 2,RFS,Y ---> S2

S2,
20#R1: ADD Y; SHOW 2,RFS,Y; ON ^FEEDER ---> S3

S3,
2": OFF ^FEEDER ---> S1
```

CLEAR - Remove SHOW Counters

CLEAR works in conjunction with SHOW. As its name suggests, CLEAR blanks out SHOW command output. For example, one might SHOW successive IRTs or other events in a trial (up to sixty) and then issue CLEAR 1,60 to erase the output of those SHOWs in preparation for the next trial. CLEAR may be used to remove any sub-range of counters and may take variables, numbers, calculations, or constants as arguments.

Syntax:

```
CLEAR P1, P2
```

Where: P1 = number, variable, array element, or constant.

P2 = number, variable, array element, or constant.

Comment: 1 <= P1 <= 60 i.e., P1 between 1 and 60 (inclusive)

P1 <= P2 <= 60 i.e., P2 greater than or equal to P1 and less than or equal to 60.

It is not necessary to include a CLEAR command to initialize or clear the output left behind by one box when the box is reloaded. Each box's SHOW area is automatically cleared when a box is loaded.

The following examples are all legal:

```
#Z10: CLEAR 40, 50 ---> SX
60#R1: CLEAR A, B ---> SX
#R2: CLEAR ^FIRST, ^LAST ---> SX
```

PRINT

The PRINT command may be used in conjunction with PRINTVARS, PRINTFORMAT, and PRINTOPTION to generate an annotated style printout on any Epson-compatible printer attached to LPT1: from within an MSN procedure, while boxes are active, irrespective of whether the printout option selected during installation is annotated or one of the stripped formats.

Syntax:

```
PRINT
```

Comment: PRINT takes no arguments.

Example:

The following code illustrates a FI-10 interval schedule with two second reinforcement. Each response is added to variable A. At the end of 60 minutes a complete annotated printout will occur of all variables even though only the A variable may have a value other than 0. No data is saved to disk.

```
S.S.1,
S1,
  10" ---> S2

S2,
  #R1: ON 1 ---> S3

S3,
  2": OFF 1; ADD B ---> S1


S.S.2,
S1,
  #R1: ADD A ---> SX


S.S.3,
S1,
  60': PRINT ---> S2

S2,
1" ---> STOPKILL
```

Handling of Printer Problems

Different procedures in the same runtime program may use different formats.

Different MPC procedures may use different combinations of printer options without interfering with the options specified by other procedures, even when different procedures with different combinations of options are being run in multiple boxes. For example, if Box 1 uses portrait and Box 2 uses landscape, each box's data will print properly.

Printouts reflect data values at the moment of actual printing, not values at the time of printing requests

When a request is made to print a box's data, either from the menu system or from within a state notation procedure, the request is not immediately fulfilled. A finite amount of time is required for the runtime system to generate the printout. Until the printout is generated, the data values within a printout may "float" during the period between the printing request being issued and the time at which the data are actually printed. For example, consider the following code:

```
DIM A = 2000
DIM Z = 2000

S.S.1,
S1,
  1": ADD A(0), Z(2000) ---> SX
```

In this example, the values of A(0) and Z(2000) are incremented every second and will always be equal. If a request to print is made after the box has finished running, the values of data printed for A(0) and Z(2000) will be identical. However, if the data for this procedure are printed while the box is still active, the values of both variables will continue to increment while the runtime system is constructing the printout. Different values are likely to be printed for the two variables, with the value of Z(2000) being larger than that of A(0) because variables and arrays are printed in alphabetical order. The basis for the discrepancy is that it takes time to generate a printout and A(0) will be placed on the printout before Z(2000).

There are, however, several different ways to ensure that data on a printout are "frozen" at the time of a printing request:

1) Issue a print command after a procedure has finished its work and it's data values will no longer change. The preceding code example could be changed to:

```
DIM A = 2000
DIM Z = 2000

S.S.1,
S1,
  1": ADD A(0), Z(2000) ---> SX
```

```
S.S.2,
S1,
  60': PRINT ---> STOPABORT    \ VALUES WILL STOP CHANGING WHEN
                               \ THIS LINE EXECUTES
```

2) Transfer the to-be-printed data to special arrays or variables that won't be updated during the time between a printing request and the generation of the printout. The code example could become:

```
DIM A = 2000
DIM B = 1
DIM Z = 2000

PRINTVARS B

S.S.1,
S1,
  #K1: SET B(0) = A(0), B(1) = Z(2000); PRINT ---> SX
       \ "FREEZE" THE DATA AND PRINT THE VALUES
       \ BY ISSUING K1 FROM THE KEYBOARD
  1": ADD A(0), Z(2000) ---> SX
```

3) Transfer an entire array with COPYARRAY.

```
DIM A = 2
DIM B = 2

PRINTVARS = B

S.S.1,
S1,
  #R1: ADD A(0) ---> SX
  #R2: ADD A(1) ---> SX
  #R3: ADD A(2) ---> SX


S.S.2,
S1,
  5': COPYARRAY A, B, 3; PRINT ---> SX
      \FROM A to B COPY 3 Elements (0,1,2) AND THEN PRINT
```

4) Print data after a box has stopped executing but before it's data are written to disk and before the box is reloaded. Simply put, if a box isn't running, its data values can't change.

In many instances it may not even matter whether data values float, particularly when the printout is being generated to get a quick look at the data, as opposed to generating archival printouts. Additionally, if small amounts of data are printed, the time interval between printing the first and last values will typically be quite small and often not detectable.

In addition to the asynchrony between printing the first and last data elements within a box that may arise when printing while a box is running, the amount of time it takes for a printout to appear on the printer varies according to a variety of factors. Typically, a printout is generated within seconds after a request. This may change, though, if a large number of printing requests have preceded the present request or if a great deal of disk-writing activity is underway. Specifically, printout generation does not occur while disks files are being written.

Queuing of Printouts and Availability of Data for Printing

When a request to print data is received by MED-PC, the request is placed in a queue or waiting line until WMPC has time to process the request. Assuming that WMPC is not occupied performing other tasks, the printout is generated in memory before actually being sent to the printer. During printout formation, the on screen memory indicators will rapidly run down until only about 5K remain. As the printout actually gets sent to the printer, memory locations are constantly released. As memory again becomes available, more printout is formed in memory.

A request to print data will be fulfilled whenever any of the following conditions are met:

1) The print request is issued while the box is still running.

2) The box is not running, but the box was terminated by an ABORT (as opposed to KILL) and the box has not been reloaded and the data has not yet been written to disk. The moment data is written to disk or abandoned; print requests will no longer be honored. However, if a print request has been issued, one may immediately write data to disk and/or reload the box without adversely affecting the printout -- the request will be honored. Note, though, that in systems running under tight memory constraints, the release of memory normally associated with writing data to disk will be delayed until the data is finished being printed.

3) The box is not running, but a request to print the box's data is still in the print queue. This feature may be of little practical value.

Example:

```
60': PRINT ---> STOPKILL
     \ DATA WILL PRINT, EVEN THOUGH TRANSITION IS TO
     \ STOPKILL BECAUSE PRINT REQUEST ISSUED BEFORE THE
     \ STOPKILL.
```

Miscellaneous

The End Date and End Time indicators on printouts will be set to 0 when a print request is issued from within a procedure or when a print is issued from the keyboard and the box is still running.

STOPABORT and STOPKILL

These commands are actually the names of two special transitions. They are placed following a transition arrow and cause the procedure to immediately stop executing. Any outputs currently turned on get shut off immediately unless turned on by LOCKON. In addition, the box's status lines on the monitor are cleared. The difference between STOPABORT and STOPKILL is that STOPABORT retains the values of all variables and array elements in memory for subsequent dumping into a file (Flush) and print can be executed before the dump. The data from procedures terminated by STOPKILL are not recoverable - the data are not placed in the dump queue. STOPABORT and STOPKILL automatically perform the same functions as their manual equivalents on the "close sessions" window. Please see the WMPC User's Manual on how to save your data manually.

Syntax:

```
---> STOPABORT
---> STOPKILL
```

Example:

```
S.S.1,
S1,
  10#R1: ADD A; ON 1 ---> S2

S2,
  2": OFF 1; IF A = 50 [] ---> STOPABORT
```

STOPABORTFLUSH

Stop Procedure Execution and Write Data to Disk

STOPABORTFLUSH is identical to STOPABORT in that it is a transition that turns off all outputs and stops procedure execution. Additionally, this command causes the data to be written to disk automatically. File structure is determined by the internal file format declared during installation and any "DISK" commands prior to State Set One. File naming defaults to the scheme declared during installation unless a custom file name is assigned from the "Open Session" window.

Executing STOPABORTFLUSH will cause all data waiting to be written to disk to be transferred to disk even if the data are awaiting transfer as the result of other boxes executing STOPABORT.

Syntax:

```
--->STOPABORTFLUSH
```

Example:

```
S.S.1,
S1,
  #R1: ADD A ---> SX
  #R2: ADD B ---> SX


S.S.2,
S1,
  60' ---> STOPABORTFLUSH
```

DATE and TIME

These commands return information about the DOS date and time. Having access to this may be useful in IF statements for setting experimental parameters on the basis of time or date information.

Syntax:

```
DATE P1, P2, P3
TIME P1, P2, P3
```

Where: P1, P2, P3 = variable or array element

Information returned by DATE into the parameters:

P1: Month
P2: Day
P3: Year (last two digits)

Information returned by TIME into the parameters:

P1: Hours (12 or 24 hour based on DOS setting)
P2: Minutes
P3: Seconds

Example:

In the following example, the calendar information is returned by DATE. If the first parameter (A) returns 10 then F is set equal to 5, establishing an FR 5. If the month is equal to anything other than 5, then the FR is set equal to 10.

```
S.S.1,
S1,
  #START: DATE A, B, C; IF A = 10 [@OctFR, @NotOctFR]
                           @OctFR: SET F = 5 ---> S2        \ FR 5
                           @NotOctFR: SET F = 10 ---> S2    \ FR10

S2,
  F#R1: ON 2 ---> S3

S3,
  2": OFF 2 ---> S1
```

Commands that Come Before the First State Set

Declaring Arrays

DIM is used to define (dimension) the size of arrays. Like variables, array names are letters of the alphabet; however declaring a letter of the alphabet to be an array precludes its use as a simple variable (i.e., "A" can not be both an array and a variable). By default, all letters are defined as variables.

Syntax:

```
DIM P1 = P2
```

Where: P1 = A letter of the alphabet to be declared as an array.

P2 = The maximum subscript of the array. Because arrays are always zero-based (zero is the lowest subscript), the number of elements is P2 + 1. The elements range from 0...P2.

Examples and Discussion:

```
DIM B = 10    \Declare "B" as an array with elements 0...10

S.S.1,
S1,
  1: Add B(5) ---> SX
```

Declaring an Array with the LIST Command

Another way to declare an array is with the LIST command. See the output section of this appendix for additional information on the other uses of the LIST command.

Declaring Constants

The clarity of MSN programs may be enhanced through the use of constants. Constants are user-defined meaningful names that may be used in place of whole numbers in MSN programs. Constants are particularly useful for providing logical names for output numbers and Z pulses. Constant names must always begin with a carat '^' and must not be more than eight characters in length.

Syntax:

```
^CONSTANT = P1
```

Where: CONSTANT = the name you are assigning

P1 = the Input or Output number being assigned to a constant.

The following code illustrates several uses of constants.

```
\Outputs
^Feeder = 1
^Light = 2

\Inputs
^LeftKey = 1

\Z PULSES
^RFBEGIN = 1
^RFEND = 2

\OFFSETS INTO C ARRAY
^RFS=0    \COUNTER 0 WILL COUNT RFS

DIM C = 5

S.S.1,
S1,
  .01": ON ^Light ---> S2

S2,
  10#R^LeftKey: ON ^Feeder; Z^RFBEGIN; ADD C(^RFS) ---> S3

S3,
  2": OFF ^FEEDER; Z^RFEND ---> S2
```

Comments:

1) It is acceptable to assign time values to constants
   (e.g., prior to the first state set: ^FIVAL=30")
2) Do not attempt to change the value of a constant within a state set
   (e.g., 1": SET ^FIVAL = 60" ---> SX)

PRINTVARS

It is often desirable to print only a subset of the variables and arrays in a procedure. This is particularly true when many of the variables are used internally by the procedure and do not contain data. Additionally, when collecting hundreds or thousands of data points per session, it would be convenient to be able to print a few key indices to the printer after every session, and yet be able to save the detailed counters to disk file for later analysis.

The above objectives may be accomplished by using the PRINTVARS command. This command may be used to declare a list of variables that will be printed whenever a PRINT command is issued. The PRINTVARS command affects printing irrespective of whether the command to print was issued from within a state table or by a keyboard command. The PRINTVARS command in no way affects the variables that will be written to disk (but a parallel command, DISKVARS, is provided).

In the absence of a PRINTVARS directive, all variables and arrays (A-Z) are printed. To print selected variables, place a PRINTVARS directive before the first state set of the procedure. The exact placement of PRINTVARS does not matter, provided that it is before the first state set.

Syntax:

```
PRINTVARS = P1, P2,..., P26
```

Where: P1...P26 are variables or arrays A through Z

Comment: PRINTVARS must be placed before the first state set.

In the following example, the PRINTVARS directive specifies that printouts should contain only variables/arrays A, J & K.

```
DIM J = 5

PRINTVARS = A, J, K
\ Printouts will contain vars. A & K and array J.
\ this statement has no effect on what is written to disk.

S.S.1,
S1,
60': PRINT ---> STOPABORT
     \ Print variables specified by printvars
     \ from within state table after 1 hour
```

PRINTFORMAT

WMPC automatically prints numbers such that 12 spaces are set aside for each number, with 8 digits reserved for the integer part of the number (to the left of the decimal), 1 space is used for the decimal and 3 spaces are provided for the decimal portion of the number. An example of a number printed in 12.3 format (the meaning of 12.3 will be detailed below) is, "12345678.123".

In many instances, it is useful to print data in other formats, particularly when trying to increase the amount of data printed per page. Placing a PRINTFORMAT statement before the first state set of the procedure will control the printed format of numbers. PRINTFORMAT takes one argument consisting of a decimal number in which the integer (to the left of the decimal) indicates the total number of spaces to be occupied by the number and the decimal portion indicates the number of spaces to be set aside for the decimal portion of to-be-printed numbers.

Syntax:

```
PRINTFORMAT = P1.P2
```

Where: P1 = number indicates the total number of spaces to be occupied by the number including the decimal point.

P2 = number indicates the number of spaces to be set aside for the decimal portion of the number.

PRINTFORMAT examples:

```
PRINTFORMAT = 5.1    \ Print in five space, with 3 to left of decimal
                     \ 1 to right as in 123.1

PRINTFORMAT = 7.2    \ 1234.12

PRINTFORMAT = 6.0    \ 123456
```

The use of a PRINTFORMAT statement has no effect upon the internal representation of numbers. If multiple PRINTFORMAT statements are used in the same .MPC procedure, then only the last one is implemented.

If the digits to the left of the decimal point exceeds the total number of spaces set aside by the printformat statement, then the general formatting rules are temporarily set aside and the number is printed in as many spaces as are needed to represent the integer portion of the number. This may result in the printed line "spilling" onto the next line on the page. If the decimal portion of a number exceeds the space allocated, the number printed is rounded to the nearest value.

PRINTOPTIONS

PRINTOPTIONS provides control over three aspects of the appearance of printouts. The options provided are FULLHEADERS vs. CONDENSEDHEADERS, NOFORMFEEDS vs. FORMFEEDS, and 80 vs. 132 characters per line. If PRINTOPTIONS is not specified in a procedure, the default printout uses a condensed header, no form feed, and 132 characters per line. When specified commas separate multiple options, and any option not specified will stay at its default value. Several samples are provided below.

Syntax:

```
PRINTOPTIONS = P1, P2
```

Where: P1=FULLHEADERS or CONDENSEDHEADERS

P2 = FORMFEEDS or NOFORMFEEDS

Comments: commas separate multiple options

CONDENSEDHEADERS and NOFORMFEEDS are the default settings and need not be specified.

The order of options is irrelevant.

Examples and Discussion:

```
PRINTVARS = A
PRINTFORMAT = 9.2
PRINTOPTIONS = FULLHEADERS

LIST A = 1234.67, 1234.67, 1234.67, 1234.67, 1234.67, 1234.67, 1234.67,
         1234.67, 1234.67, 1234.67, 1234.67, 1234.672, 1234.677

S.S.1,
S1,
1": PRINT ---> STOPKILL
```

The code above will produce a printout similar to the following:

```
Start Date:  03/10/91
End Date:  03/10/91
Subject:  0
Experiment:  0
Group:  0
Box:  1
Start Time:  14:11:32
End Time:  14:11:33
Source Code:  PRINTSAM
A:
     0:  1234.67  1234.67  1234.67  1234.67  1234.67  1234.67  1234.67
     7:  1234.67  1234.67  1234.68
```

A second option is whether a formfeed is issued after each box is printed so that data for each box begins at the top of the page. NOFORMFEEDS is the default setting, but FORMFEEDS causes the printouts to begin at the top of pages. Note that individual formfeeds may also be issued from within the runtime menu system.

Controlling Number of Columns of Data on Printouts

By judicious use of PRINTOPTIONS and PRINTFORMAT, it is possible to achieve considerable control over the number of columns of data printed on each printout. The number of columns printed is determined by the following formula:

$$\text{Number of Data Columns} = \text{Trunc} \left| \frac{(\text{PrinterColumns} - 5)}{(\text{WidthOfEachNumber} + 1)} \right|$$

Trunc refers to truncate which only takes the integer (whole number left of the decimal) part of the result. Several examples are provided on the next page.

Examples and Discussion:

Example A:

```
PRINTORIENTATION = LANDSCAPE
PRINTFORMAT = 6.0
```

This would result in the data printing in 18 columns abreast with values up to 999,999 because:

Number of Cols. = TRUNC ((132 - 5) / (6 + 1))

= TRUNC (127 / 7)
= TRUNC 18.1428
= 18

Example B:

```
PRINTFORMAT = 6.1
PRINTOPTIONS = FORMFEED
```

This would result in the data printing in 10 columns abreast with values up to 99,999.9 and an automatic form feed after each print command because:

Number of Cols. = TRUNC ((80 - 5) / (6 + 1))

= TRUNC (75 / 7)
= TRUNC 10.714
= 10

DISKVARS, DISKFORMAT, and DISKOPTIONS

DISKVARS, DISKFORMAT, and DISKOPTIONS are analogous to the PRINT commands previously discussed, but are completely separate and independent. The disk commands determine which variables are saved and the format.

Syntax:

```
DISKVARS = P1, P2,..., P26
```

Where: P1...P26 are variables or arrays A through Z

Comment: DISKVARS must be placed before the first state set.

Syntax:

```
DISKFORMAT = P1.P2
```

Where: P1 = number indicates the total number of spaces to be occupied by the number including the decimal point.

P2 = number indicates the number of spaces to be set aside for the decimal portion of the number.

Syntax:

```
DISKOPTIONS = P1, P2, P3
```

Where: P1 = 80 or 132

P2 = FULLHEADERS or CONDENSEDHEADERS

P3 = FORMFEEDS or NOFORMFEEDS

Comments: Multiple options are separated by commas

CONDENSEDHEADERS and NOFORMFEEDS are the default settings and need not be specified.

The order of options is irrelevant.

Example and Discussion:

Writing a data file with FLUSH takes place in the background, which is to say that FLUSH does not cause any interference with the speed and efficiency with which experimental events are processed; the data is written when the processor has free time. It is important to note that the amount of time that it takes to write a disk file is indeterminate; it is not advisable to make changes to the data structure(s) being written to disk until one may be reasonably certain that the data has actually been transferred to disk.

For a discussion of an analogous issue with the PRINT command, refer to the section of the manual covering that command. A way to cope with the indeterminacy is to collect data into one array and then periodically copy the contents of that array to a second array (See COPYARRAY) and then write the second array to disk.

```
\ Declare A and B with elements 0...99
DIM A = 99
DIM B = 99

\ Declare that only B will be written to disk
DISKVARS = B

S.S.1,
S1,
  #START: ---> S2

S2,    \ Whenever a response on input 1 occurs, do the following:
       \ 1)  Record the elapsed time since the last response into A(I).
       \ 2)  Clear X so that elapsed timer is reset.
       \ 3)  Update I so that the next response is recorded into the
       \     next element of A.
       \ 4)  If 100 inter-response times have been recorded, its time
       \     to transfer data to disk by doing the following:
       \       A)  Transfer the data to B so that the data is not
       \           altered by subsequent responses prior to MED-PC
       \           having an opportunity to transfer the data to disk.
       \       B)  Set all elements of A to 0 so that new data may be
       \           logged into A.  Also set I to 0 so that recording
       \           resumes at the beginning of A.
       \       C)  Issue the FLUSH command to request writing the
       \           elements of B to disk as time permits.
       \ 5)  Transition is to S2 so that the .1" IRT timer is reset
       \     whenever a response occurs.
  #R1: SET A(I) = X, X = 0; ADD I;
       IF I = 100 [@Write, @NotYet]
          @Write: COPYARRAY A, B, 100; ZERROARRAY A;
                  SET I = 0; FLUSH ---> S2
          @NotYet: ---> S2
  \The following line is the IRT timer.
  0.1": Set X = X + .1 ---> SX
        \ For some applications ADD X may be substituted
        \ in the Output Section for SET X = X + 0.1
```

Y2KCOMPLIANT

Y2K issues: A new MSN directive, "Y2KCOMPLIANT," has been created. The command gets placed before the first state set and takes no arguments. The consequence of including this directive is that all years are 4 digits on printouts (disk and paper) and in all data files.

Syntax:

```
Y2KCOMPLIANT
```

Example:

```
Y2KCOMPLIANT

DISKOPTIONS = FULLHEADERS
PRINTOPTIONS = FULLHEADERS

S.S.1,
S1,
  1" ---> SX
```

INDEX

' (Minutes)....68
" (Seconds) 68
#K....66
#R 64
#START....64
#T 69
#Z 65
ADD....83
ALERTOFF 82
ALERTON 82
BIN 85
BOX....95
BOXNUMBER 95
BTIME 96
CLEAR 105
Commands that Come Before the First State Set....112
Compound IF Statements 91
Controlling Number of Columns of Data on Printouts 116
COPYARRAY....101
CURRENTDATE 96
CURRENTHOURS 96
CURRENTMINUTES....96
CURRENTMONTH....96
CURRENTSECONDS 96
CURRENTYEAR 96
DATE....111
DATETODAY 96
Declaring an Array with the LIST Command....112
Declaring Arrays....112
Declaring Constants....112
DISKFORMAT....117
DISKOPTIONS....117
DISKVARS 117
ENDDATE 95
ENDHOURS....95
ENDMINUTES....95
ENDMONTH....95
ENDSECONDS 95
ENDYEAR 95
EXPNUMBER....95
GETVAL 102
GROUPNUMBER....95
Handling of Printer Problems....107
IF 88
Internal Representation of Time....70
K-Pulse Theory Of Operation And Technical Details 79

K-pulses 78
LIMIT 87
LIST 97
LOCKOFF 73
LOCKON 73
Miscellaneous 109
Numeric Format of SHOW Output 104
OFF 73
ON 72
Overlapping Inputs and Outputs 74
PRINT 106
PRINTFORMAT 114
PRINTOPTIONS 115
PRINTVARS 113
Processing Efficiency of the K-pulse 80
Queuing of Printouts and Availability of Data for Printing 109
RANDD 99
RANDI 100
SECSTODAY 96
SET 84
SHOW 103
Special Identifiers 92
STARTDATE 95
STARTHOURS 95
STARTMINUTES 95
STARTMONTH 95
STARTSECONDS 95
STARTYEAR 95
STOPABORT 110
STOPABORTFLUSH 110
STOPKILL 110
SUB 83
SUBJECTNUMBER 95
The Special Variable "BOX" 80
TIME 111
Time Inputs Less Than the Resolution Value 70
Updating the SHOW Display 104
Using Logical OR "!" with Input Commands 71
WITHPI 93
Y2KCOMPLIANT 120
ZEROARRAY 102
Z-pulse Depth Checking 77
Z-pulses 74